1610.6.6 Intersecting drifts: When one snow drift intersects another at an angle as shown in Figure 1610.9, the unit snow load at any point shall be not less than the greater of the unit *loads* from the two individual drifts, plus the unit load of the underlying uniform snow layer.

1610.7 Sliding snow from sloped upper roofs: Two cases of drift loading shall be considered for roofs which are located below upper sloped roofs, as shown in Figure 1610.10 and as follows:

(a) Case I Drift loading due to snow from the upper roof computed in accordance with 780 CMR 1610.6.1, but without load from sliding snow (W_{bu} is the full width of the upper roof as shown in Figure 1610.10.)

(b) Case II Drift loading due to snow from the lower roof computed in accordance with 780 CMR 1610.6.1 and a sliding snow surcharge load as specified below and as shown in Figure 1610.10.

The maximum intensity of the sliding snow load, P_{ds} , shall be:

$$P_{ds} = \frac{AW_a}{W_s}(P_{\ddot{u}}) \qquad \text{(Equation 18)}$$

where W_a and W_s are defined in Figure 1610.10 and the coefficient A is defined as follows:

(a) For roof surfaces of metal and slate, and for other roof surfaces smoother than mineral surfaced roofing: If the angle of slope of the upper roof, "*a*", as shown in Figure 1610.10 is equal to or greater than 15 degrees (slope 3.2 in 12), A = 1.6; if "a" is less than 15 degrees, A = 0 (no sliding snow load).

(b) For roof surfaces of mineral surfaced roofing or rougher surfaces:

If "a" is equal to or greater than 25 degrees (slope 5.6 in 12), A = 1.0;

if "a" is less than 25 degrees, A = 0.

The value of W_s , the width of the sliding snow surcharge, shall be computed as follows:

(a) For "*a*" less than or equal to 45 degrees,

$$W_s = h_r \qquad \text{(Equation 19)}$$

or

$$W_s = \frac{W_a}{4} \qquad \text{(Equation 20)}$$

whichever is greater.

(b) For "a" greater than or equal to 45?

$$W_s + h_r(\cot a) \qquad \text{(Equation 21)}$$

or

$$W_s = \frac{W_a}{4} \qquad \text{(Equation 22)}$$

whichever is greater

1610.7.1 Snow guards: Sliding snow from an adjacent sloping high roof need not be considered on the low roof if proper snow guards are provided on the high roof. In this case, the sloping roof with snow guards shall be designed for the unit snow *loads* required for a flat roof.

1610.8 Snow pockets or wells: Account shall be taken of the load effects of potentially excessive snow accumulation in pockets or wells of roofs or decks.

1610.9 Snow storage and collection areas: Consideration of potentially excessive snow accumulation shall be given to portions of structures which may be designed or used as snow collection or storage areas during and after snow removal operations.

780 CMR 1611.0 WIND LOAD

1611.1 Wind load zones: The locations of *wind load* zones are shown in the Figures 1611.1A, 1611.1B, 1611.1C maps. Zone 1 consists of the Counties of Berkshire, Franklin, Hampshire and Hampden; Zone 2 consists of the County of Worcester; and Zone 3 consists of the Counties of Essex, Middlesex, Suffolk, Norfolk, Plymouth, Bristol, Barnstable, Dukes and Nantucket.

1611.2 Exposures: Exposure is defined as a measure of terrain roughness and is classfied as follows:

Exposure A: centers of large cities and very rough, hilly terrain. Exposure A applies for downtown areas only when the terrain for at least one half mile upwind of the structure is heavily built up, with at least 50% of the buildings being in excess of four stories, and when Exposure B prevails beyond this boundary.

Exercise caution in using these reduced wind pressures for buildings and structures on high ground in the midst of cities or rough terrain.

1611.2.1 Special exposures: Consideration shall be given to the application of a more severe exposure (e.g., Exposure C instead of Exposures B or A) when the ground slope near the site of a structure changes abruptly, in order to account for the resulting higher wind speeds near ground level.

1611.3 Reference wind velocities: The reference wind velocity for each *wind load* zone is the "fastest-mile" wind velocity, in miles per hour, at 30 feet about the ground (V_{30}) for Exposure C, as shown in Table 1611.3:

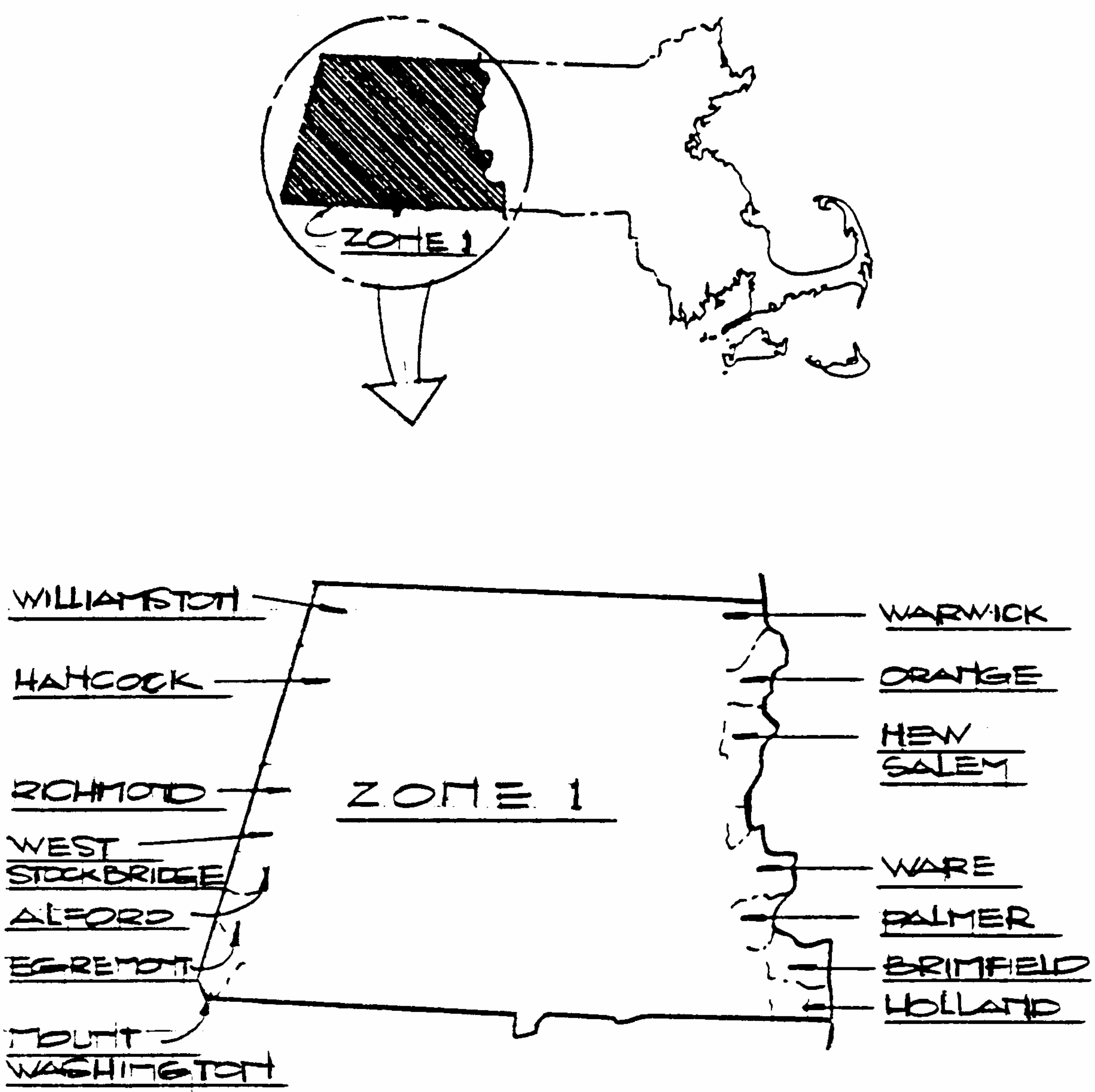
Exposure B: suburban areas, towns, city outskirts, wooded areas, and rolling terrain. Exposure B applies only when the terrain for at least one half mile upwind is a continuous urban development, forest, wooded area, or rolling terrain.

Exposure C: open level terrain with only scattered buildings, structures, trees or miscellaneous obstructions, open water, or shorelines.

Table 1611.3

Zone	V_{30} (mph)
1	70
2	80
3	90

Figure 1611.1A
WIND LOAD MAP - ZONE 1

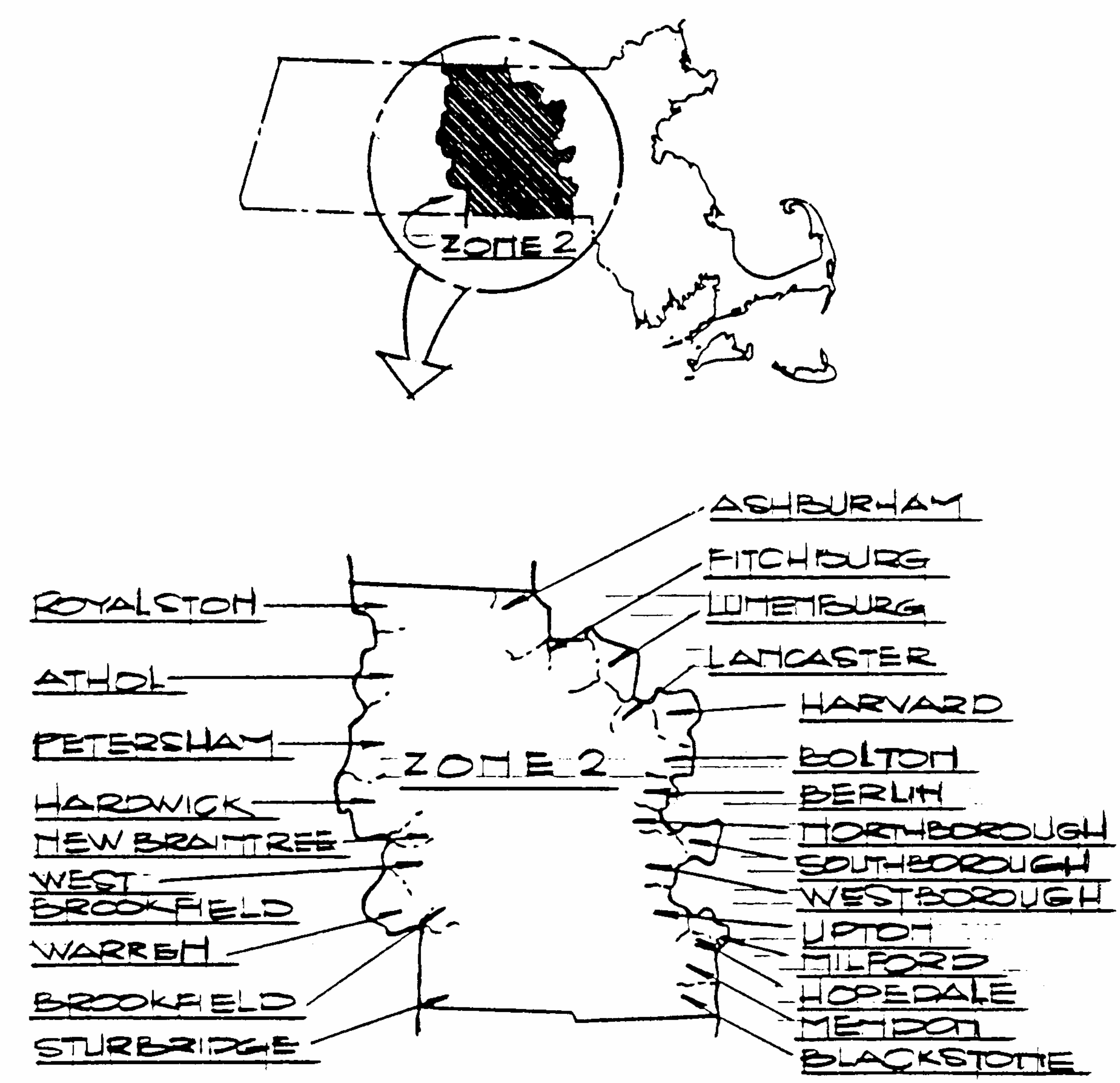


List of Towns: Wind Load Zones
Zone 1

Adams	Chicopee	Granville	Lenox	North Adams	Sheffield	Wendell
Agawam	Clarksburg	Great Barrington	Leverett	Northampton	Shelbourne	W. Springfield
Alford	Colrain	Greenfield	Leyden	Northfield	Shutesbury	W. Stockbridge
Amherst	Conway	Hadley	Longmeadow	Orange	S. Hadley	Westfield
Ashfield	Cummington	Hampden	Ludlow	Otis	Southampton	Westhampton
Becket	Dalton	Hancock	Middlefield	Palmer	Southwick	Whately
Belchertown	Deerfield	Hatfield	Monroe	Pelham	Springfield	Wilbraham
Bernardston	E. Longmeadow	Hawley	Monson	Peru	Stockbridge	Williamsburgh
Blandford	Easthampton	Heath	Montague	Pittsfield	Sunderland	Wiliamstown
Brimfield	Egremont	Hinsdale	Monterey	Plainfield	Tolland	Windsor

Buckland	Erving	Holland	Montgomery	Richmond	Tyringham	Worthington
Charlemont	Florida	Holyoke	Mount Washington	Rowe	Wales	
Cheshire	Gill	Huntington	New Ashford	Russell	Ware	
Chester	Goshen	Lanesborough	New Marlborough	Sandisfield	Warwick	
Chesterfield	Granby	Lee	New Salem	Savoy	Washington	

FIGURE 1611.1b
WIND LOAD MAP - ZONE 2

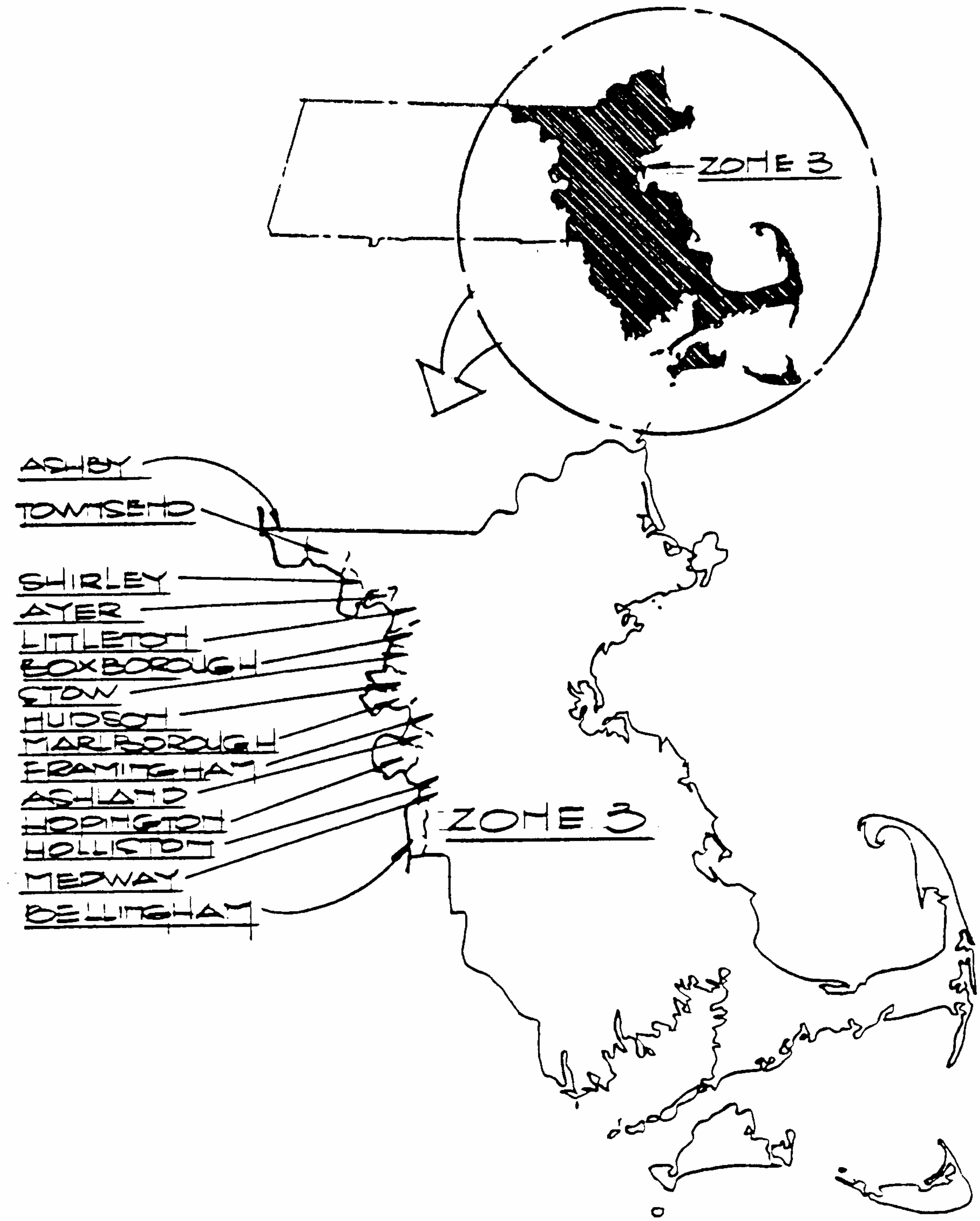


List of Towns: Wind Load Zones
Zone 2

Asburnham	Hopedale	Royalston
Athol	Hubbardston	Rutland
Auburn	Lancaster	Shrewsbury

Barre	Leicester	Southborough
Berlin	Leominster	Southbridge
Blackstone	Lundenburg	Spencer
Bolton	Mendon	Sterling
Boylston	Milford	Sturbridge
Brookfield	Millbury	Sutton
Charlton	Millville	Templeton
Clinton	New Braintree	Upton
Douglas	N. Brookfield	Uxbridge
Dudley	Northborough	Warren
E. Brookfield	Northbridge	Webster
Fitchburg	Oakham	W. Boylston
Gardner	Oxford	W. Brookfield
Grafton	Paxton	Westborough
Harvard	Petersham	Westminster
Hardwick	Phillipston	Winchedon
Holden	Princeton	Worcester

FIGURE 1611.1C
WIND LOAD MAP - ZONE 3



List of Towns: Wind Load Zones
Zone 3

Abington	Boston	Cohasset	Fall River	Hingham	Mansfield	Nahant
Acton	Boxborough	Concord	Falmouth	Holbrook	Marblehead	Nantucket

Accushnet	Boxford	Danvers	Foxborough	Holliston	Marion	Natick
Amesbury	Bourne	Dartmouth	Framingham	Hopkinton	Marlborough	Needham
Andover	Braintree	Dedham	Franklin	Hudson	Marshfield	New Bedford
Arlington	Brewster	Dennis	Freetown	Hull	Mashpee	Newbury
Ashby	Bridgewater	Dighton	Gay Head	Ipswich	Mattapoisett	Newburyport
Ashland	Brockton	Dover	Georgetown	Kingston	Maynard	Newton
Attleboro	Brookline	Dracut	Gloucester	Lakeville	Medfield	Norfolk
Avon	Burlington	Dunstable	Gosnold	Lawrence	Medford	N. Andover
Ayer	Cambridge	Duxbury	Groton	Lexington	Medway	N. Attleboro
Barnstable	Canton	E. Bridgewater	Groveland	Lincoln	Melrose	N. Reading
Bedford	Carlisle	Eastham	Halifax	Littleton	Merrimac	Norton
Bellingham	Carver	Easton	Hamilton	Lowell	Methuen	Norwell
Belmont	Chatham	Edgartown	Hanover	Lynn	Middleborough	Norwood
Berkley	Chemlsford	Essex	Hanson	Lynnfield	Middleton	Oak Bluffs
Beverly	Chelsea	Everett	Harwich	Malden	Millis	Orleans
Billerica	Chilmark	Fairhaven	Haverhill	Manchester	Milton	Peabody
Pembroke	Rehoboth	Scituate	Stow	Truro	Wellesley	Westwood
Pepperell	Revere	Seekonk	Sudbury	Tyngsborough	Wellfleet	Weymouth
Plainville	Rochester	Sharon	Swampscott	Vineyard Haven	Wenham	Whitman
Plymouth	Rockland	Sherborn	Swansea	Wakefield	W. Bridgewater	Wilmington
Plympton	Rockport	Shirley	Taunton	Walpole	Westford	Winchester
Provincetown	Rowley	Somerset	Tewksbury	Waltham	W. Newbury	Winthrop
Quincy	Salem	Somerville	Tisbury	Wareham	Weston	Woburn
Randolph	Salisbury	Stoneham	Topsfield	Watertown	Westport	Wrentham
Raynham	Sandwich	Stoughton	Townsend	Wayland	W. Tisbury	Yarmouth
Reading	Saugus					

1611.4 Reference wind pressures: Reference wind pressures for the various exposures and wind zones are given in the following Table 1611.4. The tabulated pressures are combined windward and leeward pressures representing the overall effect of the wind on essentially rectangular structures, and account for typical gust effects as found in ordinary buildings. These pressures do not account for buffeting or channeling caused by positions of nearby structures, vortex shedding, or wind sensitive dynamic properties of a particular structure.

1611.5 Wind loads on structures as a whole: All buildings and enclosed or partially enclosed structures shall be designed to withstand a total *wind load* acting on the structure as a whole determined by applying the appropriate reference wind pressures given in Table 1611.4 or 1611.4a, to the vertical projected area, normal to the wind direction of the vertical surfaces of the structure, plus the appropriate wind forces on the roof as specified in 780 CMR 1611.8. Consideration shall be given to wind acting in all directions.

1611.5.1 Simultaneous wind forces on orthogonal sides: For structures which are essentially rectangular in plan, or whose plan shape is made up of rectangular parts, only wind directions normal to the sides of the structure need be considered, provided that 0.7 times the effects of the wind acting simultaneously normal to adjacent orthogonal sides shall also be considered when it produces more severe effects in the structural support system. Factors other than 0.7

may be used if substantiated by appropriate wind tunnel tests.

1611.5.2 Wind force distribution: The total wind force on the vertical surfaces of a structure prescribed in 780 CMR 1611.5 shall be distributed 6/10 to the windward surfaces (as a positive pressure) and 4/10 to the leeward surfaces (as a suction). Other distributions may be used if substantiated by appropriate wind tunnel tests.

1611.6 Vertical parts of structures: Vertical parts of structures that are subjected directly to the wind, and their local supporting elements, shall be designed to resist the pressures listed in Table 1611.6, normal to the surface, inward or outward. The pressures listed in the table represent the combined internal and external pressures. A local supporting element of a vertical part subjected directly to the wind shall be defined as a wall assembly, a stud, a mullion, a girt, or a similar item which distributes the *wind load* from the vertical part to the principal structural system of the structure.

TABLE 1611.4
REFERENCE WIND PRESSURE (POUNDS PER SQUARE FOOT)

Height above grade	Zone 1			Zone 2			Zone 3		
	Exposure			Exposure			Exposure		
H (feet)	A	B	C	A	B	C	A	B	C
0 - 50	11	12	12	11	17	17	14	21	21
50 - 100	11	12	18	11	17	24	14	21	31
100 - 150	11	16	22	14	21	29	18	26	37
150 - 200	13	18	25	17	24	33	22	30	41
200 - 250	15	20	27	20	27	36	25	34	45
250 - 300	17	22	29	22	30	39	28	37	48
300 - 400	19	25	31	25	33	42	32	41	52
400 - 500	22	28	34	29	37	46	36	46	57
500 - 600	24	30	37	33	41	49	41	51	61
600 - 700	27	33	39	36	44	52	45	55	65
700 - 800	29	35	41	39	47	55	48	58	68
800 - 900	31	37	43	41	49	57	52	62	72
900 - 1000	33	39	45	44	52	59	55	65	74

See table 1611.1a for empirical wind pressure formulas

TABLE 1611.4a
EMPIRICAL WIND PRESSURE FORMULAS[a]

Zone 1			Zone 2			Zone 3		
Exposure			Exposure			Exposure		
A	B	C	A	B	C	A	B	C
$p = 30\,(h/800)^{0.55}$	$p = 36\,(h/800)^{0.45}$	$p = 42\,(h/800)^{0.35}$	$p = 40\,(h/800)^{0.55}$	$p = 48\,(h/800)^{0.45}$	$p = 56\,(h/800)^{0.35}$	$p = 50\,(h/800)^{0.55}$	$p = 60\,(h/800)^{0.45}$	$p = 70\,(h/800)^{0.35}$

Note a: Empirical wind pressure formulas may be used in lieu of the reference wind pressures in table 1611.1

TABLE 1611.6
WIND PRESSURES ON PARTS OF STRUCTURES AND LOCAL SUPPORTING ELEMENTS

Location of applied wind pressure	Tributary *wind load* area of part or local supporting element	Required Design Pressures: Reference pressure of 780 CMR 1611.4 multiplied by[1]	Required Design Pressures: But not less than	Required Design Pressures: But need not be greater than
Within salient corner area[2]	Any	1.7	20 psf	70 psf
Beyond salient corner area	Less than or equal to 200 sf	1.2	20 psf	50 psf
Beyond salient corner area	Greater than 200 sf	0.8	15 psf	50 psf

Note 1: For partially enclosed structures, where any side is more than 35% open, add a factor of 0.3 to the coefficients of this column of the table

Note 2: The salient corner shall be defined as the vertical surface located within a distance of 1/10 the least width of the structure, but not more than ten feet, from a prominent (salient) corner.

TABLE 1611.8
EXTERNAL WIND PRESSURES ON ROOFS

External Wind Pressure - flat, gable, shed roofs (wind perpendicular to ridge)

Roof pitch: Degrees	Roof pitch: Rise/run	Multiples of reference wind pressure of 780 CMR 1611.4: Windward slope Positive pressure	Windward slope Suction	Leeward slope Suction
0-20	Flat to 4/12	---	0.6	0.5
20-30	4/12 to 7/12	0.2	0.5	0.5
30-40	7/12 to 10/12	0.3	0.4	0.5
40-50	10/12 to 14/12	0.4	0.3	0.5
50-90	14/12 to vertical	0.6	---	0.5

External Wind Pressure - arch shaped roofs (wind perpendicular to ridge)

Rise to span ratio	Multiples of reference wind pressure of 780 CMR 1611.4: Windward quarter Positive pressure	Windward quarter Suction	Center half Suction	Leeward quarter Suction
Less than 2/10	0.2	0.7	0.7	0.4
2/10 to 3/10	0.3	---	0.8	0.4
3/10 to 6/10	0.6	---	1.0	0.4

External wind pressure - flat, gable, shed or arched shaped roofs (wind parallel to ridge)

All	Suction of 0.6 multiplied by the reference wind pressure of 780 CMR 1611.4

1611.7 Wind loads on roofs: Roofs and their supporting structure shall be designed to resist the combined effects of the external and internal wind pressures specified in 780 CMR 1611.8 through 1611.11. All pressures specified shall be considered to act normal to the roof surface. When applying the reference wind pressures of 780 CMR 1611.4 to the provisions of 780 CMR 1611.8 through 1611.11, the reference wind pressures shall be for a height equal to the average height of the roof eave above grade.

1611.8 External wind pressures on roofs of enclosed structures: Except as specified otherwise in 780 CMR 1611.11, external wind pressures shall be specified in Table 1611.8, or 780 CMR 1611.8. Where both positive pressure and suction are specified, the effects of each shall be evaluated.

1611.8.1 Roof shapes not specified: For roof shapes not specified herein, external wind pressures shall be determined as specified in 780 CMR 1611.13 but the minimum suction effect shall be equal to 0.6 times the reference wind pressure of 780 CMR 1611.4.

1611.9 Internal wind pressures on roofs of enclosed structures: Except as specified otherwise in 780 CMR 1611.10, internal wind pressures shall be 0.2 times the reference wind pressure given in 780 CMR 1611.4. The internal pressure shall be applied as a positive pressure or a suction, whichever gives the greater structural effect when added to the external pressure, for the design of each structural component.

1611.10 Wind pressures on roofs over nonenclosed or partially enclosed structures: Except as specified otherwise in 780 CMR 1611.11, wind pressures for roofs of partially enclosed or nonenclosed structures shall be as follows:

1. When a structure is partially enclosed, with each side not more than 35% open, the wind pressure shall be the same as for an enclosed structure.
2. When a structure is partially enclosed, with openings essentially all on one side, and when that side is more than 35% open, external wind pressure shall be as specified in Table 1611.4 or Table 1611.4a and internal wind pressures shall be as specified in 780 CMR 1611.9 except that the value of internal wind pressure shall be equal to 0.5 times the reference wind pressure given in Table 1611.3.
3. For all other cases of partially enclosed structures, or for nonenclosed structures, the combined effect of the wind pressures above and below roofs shall be equal to 1.25 times the values specified in Table 1611.8 for the corresponding roof shapes and wind directions.

1611.11 Wind pressures for parts of roofs: Parts of roofs that are subject directly to the wind, and their local supporting elements, shall be designed to resist the following pressures in an outward direction:

1. Where parts of roofs subjected directly to the wind are located within a distance of 1/10 the least width of a structure, but not more than ten feet, from the ridge, eave, or cornice, they shall resist a pressure 1.7 times the reference wind pressure given in Table 1611.4 (representing the combined internal and external pressures).
2. Where parts of roofs subjected directly to the wind are located outside the zones specified in 780 CMR 1611.11.1 they shall resist pressures as specified in 780 CMR 1611.8 through 1611.10 and Table 1611.8.

A local supporting element of a part of a roof shall be defined as a roof deck element, purlin, rafter, or similar item which distributes the *wind load* from the roof part to the principal structural system of the structure.

1611.12 Wind load on signs, towers, exposed framing, tanks, stacks and chimneys: Signs, towers, exposed framing, tanks, stacks, chimneys, and similar structures, or parts thereof, shall be designed for wind forces determined by applying coefficients given for the applicable structure in Tables 12 through 16 of ASCE-7 for the applicable reference wind pressures given in Table 1611.4, multiplied by 0.75.

1611.12.1 Shielding: Shielding effect of one element by another shall not be considered when the distance between them exceeds four times the projected smallest dimensions of the windward element.

1611.12.2 Signs: For open or solid outdoor signs with ratios of dimensions with the limits stated below, a *wind load* applied uniformly over the area of the sign and determined by the lesser of 1.2P on the projected gross area within the outside dimensions of the sign, or 1.6P on the net projected area of the sign; whichever is less, may be used in lieu of the *loads* given in ASCE 7, where "P" is the reference wind pressure given in Table 1611.4 for a height equal to the average height of the sign above the ground.

1. Ground supported signs (whose bottom is 0.25 times the vertical height from the ground to the top of the sign): height to width ratio less than ten.
2. Above ground signs: largest to smallest dimension ratio less than 20.

1611.13 Wind forces and pressures using wind tunnel tests: Design wind forces and pressures may be determined by appropriate wind tunnel tests on specific structures as stipulated by the responsible design engineer and approved by the building official.

The wind tunnel test program shall adequately represent the relevant properties of the structure and its surroundings and the oncoming wind flow. The wind tunnel tests may be combined with a detailed statistical study of meteorological records, including high level wind velocity and direction, from stations near the proposed structure. The wind effects used for design of the structure shall be not less than those corresponding to an event having an annual probability of occurrence of 0.01. In lieu of a detailed statistical study of meteorological records, the appropriate reference wind velocity stipulated in 780 CMR 1611.3 may be used.

The wind forces and pressures so determined, plus an appropriate allowance for stack effects and internal pressures may be used for the design of the structure as a whole, and its individual parts. However, these values of forces and pressures shall not be less than .8 of the values required by 780 CMR 1611.5, 1611.7 and 1611.12, as applicable, for reference wind pressures for Exposure A and the appropriate wind zone specified in Table 1611.4.

1611.14 Uplift, overturning and sliding:

1611.14.1 Anchorage, roofs and walls: All parts of a structure subjected directly to the wind shall be anchored to the supporting structure, to resist specified *wind loads* inwardly or outwardly.

1611.14.2 Anchorage, structural system: The design of the structural system and its elements for uplift, overturning moment, or horizontal shear, or their combination, shall provide anchorage resistance required by the load combinations specified in 780 CMR 1616.0

1611.15 Eccentricity of wind forces: Consideration shall be given to the effects of specified wind forces being applied eccentrically to the center of rigidity of a structure.

780 CMR 1612.0 EARTHQUAKE LOADS

1612.1 Purpose: 780 CMR 1612.0 presents criteria for the design and construction of buildings and structures subject to earthquake ground motions. The purposes of 780 CMR 1612.0 is to minimize the hazard to life to occupants of all buildings and non building structures, to increase the expected performance of higher occupancy structures as compared to ordinary structures, and to improve the capability of essential facilities to function during and after an earthquake. Because of the complexity of and the great number of variables involved in seismic design (e.g. the variability in ground motion, soil types, dynamic characteristics of the structure, material strength properties and construction practices), 780 CMR 1612.0 presents only minimum criteria in general terms. These minimum criteria are considered to be prudent and economically justified for the protection of life safety in buildings subject to earthquakes. It must be emphasized that absolute safety and prevention of damage, even in an earthquake event with a reasonable probability of occurrence, cannot be achieved economically for most buildings.

The "design earthquake" ground motion levels specified herein may result in both structural and non structural damage. For most structures designed and constructed according to 780 CMR 1612.0, it is expected that structural damage from a major earthquake may be repairable but the repair may not be economical. For ground motions larger than the design levels, the intent of 780 CMR 1612.0 is that there be a low likelihood of building collapse.

1612.2 General: Every building and structure shall be designed and constructed to resist the effects of earthquake motions determined in accordance with this section. Additions and changes of occupancy to existing buildings and structures shall be designed and constructed to resist the effects of earthquake motions determined in accordance with this section. Special structures, including but not limited to vehicular bridges, transmission towers, industrial towers and equipment, piers and wharves, and hydraulic structures shall be designed for *earthquake loads* utilizing an approved, substantiated analysis.

Exceptions:

1. Detached one- and two-family dwellings are exempt from the requirements of 780 CMR 1612.2.
2. Agricultural storage buildings which are intended only for incidental human occupancy are exempt from the requirements of 780 CMR 1612.2

1612.2.1 Additions to existing buildings: An addition to an existing building shall be designed and constructed in accordance with the requirements of 780 CMR 34.

1612.2.2 Change of occupancy: Where a change of occupancy occurs in an existing building, the building shall conform to the provisions of 780 CMR 34.

1612.2.3 Seismic ground acceleration maps: The effective peak velocity-related acceleration (A_v) and the effective peak acceleration (A_a) shall each be taken as 0.12g throughout Massachusetts for the purposes of seismic design in accordance with 780 CMR.

1612.2.4 Site-specific response spectra: Where site-specific response spectra are required for buildings assigned to Seismic Performance Category D in accordance with Table 1612.4.6.2. the site-specific response spectra shall be developed based on ground motions which have a 90% probability of not being exceeded in 50 years.

1612.2.5 Seismic Hazard Exposure Groups: All buildings shall be assigned to one of the Seismic Hazard Exposure Groups in accordance with Table 1612.2.5.

1612.2.5.1 Multiple occupancies: Where a building is occupied for two or more occupancies not included in the same Seismic Hazard Exposure Group, the building shall be assigned the classification of the highest Seismic Hazard Exposure Group occupancy.

Table 1612.2.5
SEISMIC HAZARD EXPOSURE GROUP

Seismic Hazard Exposure Group type and description	Nature of occupancy
Group I	All occupancies except those listed below
Group II Seismic Hazard Exposure Group II buildings are those which have a substantial public hazard due to occupancy or use,. including buildings containing any one or more of the indicated occupancies	1. Use Group A in which more than 300 people congregate in one area. 2. Use Group E with an occupant load greater than 250. 3. Use Group B used for college or adult education with an occupant load grater than 500. 4. Use Group I-2 with an occupant load greater than 50, not having surgery or emergency treatment facilities. 5. Use Group I-3 6. Power generating stations and other public utility facilities not included in Seismic Hazard Exposure Group III 7. Any other occupancy with an occupancy load greater than 5,000
Group III Seismic Hazard Exposure Group III buildings are those having essential facilities which are required for post-earthquake recovery, including buildings containing any one ore more of the indicated occupancies.	1. Fire, rescue and police stations 2. Use Group I-2 having surgery or emergency treatment facilities. 3. Emergency preparedness centers 4. Post-earthquake recovery vehicle garages. 5. Power-generating stations and other utilities required as emergency backup facilities. 6. Primary communcation facilities. 7. High toxic materials as defined by 780 CMR 307.0 where the quantify of the material exceeds the exempt amounts of 780 CMR 307.8

1612.2.6 Group III building protected access: Where operational access to a Seismic Hazard Exposure Group III building is required through an adjacent building, the adjacent building shall conform to the requirements for Group III buildings. Where operational access is less than ten feet (30.48 m) from the interior lot line or another building on the same lot, protection from potential falling debris from adjacent property shall be provided by the owner of the Seismic Hazard Exposure Group III building.

1612.2.7 Seismic Performance Category: All buildings shall be assigned a Seismic Performance Category as follows;

Seismic Hazard Exposure Group (from Table 1612.2.5)	Seismic Performance Category
I	C
II	C
III	D

1612.3 Definitions: The following words and terms shall, for the purposes of 780 CMR 1612.0 and as used elsewhere in 780 CMR, have the meanings shown herein.

Acceleration:

Effective peak: Coefficient Aa, in accordance with 780 CMR 1612.2.3, for determining the prescribed seismic forces.

Effective peak velocity-related: Coefficient Av, in accordance with 780 CMR 1612.2.3, for determining the prescribed seismic forces.

Base: The level at which the horizontal seismic ground motions are considered to be imparted to the building.

Base shear: Total design lateral force or shear at the base of the building.

Bay (part of a structure): The space between two adjacent piers or mullions or between two adjacent lines of columns.

Design earthquake: The earthquake that produces ground motions at the site under consideration which has a 90% probability of not being exceeded in 50 years.

Designated seismic systems: The seismic-resisting system and those architectural, electrical and mechanical systems and their components that require special performance characteristics.

Diaphragm: A horizontal, or nearly horizontal, portion of the seismic-resisting system, which is designed to transmit seismic forces to the vertical elements of the seismic-resisting system.

Frame:

Braced: An essentially vertical truss, or its equivalent, of the concentric or eccentric type that is provided in a loadbearing wall, building frame or dual system to resist seismic forces.

Concentrically braced frame (CBF): A braced frame in which the members are subjected primarily to axial forces.

Eccentrically braced frame (EBF): A diagonally braced steel frame in which at least one end of each brace frames into a beam a short distance from a beam-column joint or from another diagonal brace. These short beam segments are called link beams. The following EBF definitions apply:

Diagonal brace: A member of an EBF placed diagonally in the bay of the frame.

Lateral support members: Secondary members designed to transmit seismic-resisting system.

Link beam: The horizontal beam in an EBF which has a length of the clear distance between the diagonal braces or between the diagonal brace and the column face.

Link beam end web stiffeners: Vertical web stiffeners placed on the sides of the web at the diagonal brace end(s) of the link beam.

Link beam intermediate web stiffener: Vertical web stiffeners placed within the link beam.

Link beam rotation angle: The angle between the beam outside of the link beam and the link beam occurring at a total story drift of the deflection amplification factor (C_d) times the elastic drift at the prescribed design forces. The rotation angle is permitted to be computed assuming the EBF bay is deformed as a rigid, ideally plastic mechanism.

Intermediate moment frame: A frame in which members and joints are capable of resisting forces by flexure as well as along the axis of the members. Intermediate moment frames of reinforced concrete shall conform to 780 CMR 1903.3.2.

Ordinary moment frame: A frame in which members and joints are capable of resisting forces by flexure as well as along the axis of the members.

Space frame: A structural system composed of interconnected members, other than loadbearing walls, that is capable of supporting vertical *loads* and, if so designed, resist the seismic forces.

Special moment frame: A frame in which members and joints are capable of resisting forces by flexure as well as along the axis of the members. Special moment frames shall conform to the applicable requirements of 780 CMR 1903.0 or 2204.0.

Frame system:

Building: A structural system with an essentially complete space frame providing support for vertical *loads*. Seismic force resistance is provided by shear walls or braced frames.

Dual: A structural system with an essentially complete space frame providing support for vertical *loads*. A moment-resisting frame shall be provided which shall be capable of resisting at least 25% of the prescribed seismic forces. The total seismic force resistance is provided by the combination of the moment-resisting frame together with shear walls or braced frames in proportion to their relative rigidities.

Moment resisting: A structural system with an essentially complete space frame providing support for vertical *loads*. Seismic force resistance is provided by special, intermediate or ordinary moment frames capable of resisting the total prescribed forces.

High-temperature energy source: A fluid, gas or vapor whose temperature exceeds 220?F (104?C).

Inverted pendulum-type structures: Structures that have a large portion of their mass concentrated near the top and thus have essentially one degree of freedom in horizontal translation. The structures are usually T-shaped with a single column supporting the beams or slab at the top.

Light-framed wall with shear panels: Wood or steel stud walls with finishes other than masonry veneer. Loadbearing wall system: A structural system with loadbearing walls providing support for all, or major portions of, the vertical *loads*. Shear walls or braced frames provide seismic force resistance.

P-Delta effect: The secondary effect on shears and moments of frame members due to the action of the vertical *loads* induced by displacement of the building frame resulting from lateral forces.

Resilient stable-mounting system: A system incorporating helical springs, air cushions, rubber-in-shear mounts, fiber-in-shear mounts, or other comparable approved systems. The force displacement ratios are equal in the horizontal and vertical directions

Restraining device: A device used to limit the vertical or horizontal movement of the mounting system due to earthquake motions.

An alternate procedure using structural concepts other than as specified in this section may be used, if approved by the building offical, to establish the design forces and their distribution. Such an alternate procedure may be permitted where evidence is submitted to the building official showing that equivalent ductility and energy dissipation are provided, and the corresponding

Elastic: A fixed restraining device that incorporates an elastic element to reduce the seismic forces transmitted to the structure due to impact from the resilient mounting system.

Fixed: A nonyielding or rigid type of restraining device.

Seismic activated: An interactive restraining device that is activated by earthquake motion.

Seismic-resisting system: That part of the structural system that has been considered in the design to provide the required resistance to the seismic forces prescribed herein.

Shear wall: A wall, loadbearing or nonloadbearing, designed to resist seismic forces, from other than its own mass, acting in the plane of the wall.

Story drift ratio: The story drift divided by the story height.

Story shear: The summation of design lateral forces at levels above the story under consideration.

1612.4 Structural design requirements:

1612.4.1 Design Basis: The seismic analysis and design procedures utilized in the design of buildings and their structural components shall be in accordance with the requirements of 780 CMR 1612.4. The design seismic forces and their distribution over the height of the building shall be in accordance with the procedures in 780 CMR 1612.5 or 1612.6. The corresponding internal forces in the structural components of the building shall be determined using a linearly elastic model. internal forces and deformations in the structural components are determined using a model consistent with the approved procedure.

Individual structural members shall be designed for the shear forces, axial forces and moments determined in accordance with 780 CMR 1612.4. Connections shall be designed to develop the strength of the connected members or the analysis force, whichever is less. The design story drift of the building, calculated as specified herein, shall not exceed the allowable story drift of 780 CMR 1612.4.8, when the building is subjected to the design seismic forces.

A continuous load path, or paths, with adequate strength and stiffness shall be provided to transfer all forces from the point of application to the final point of resistance. The foundation shall be designed to resist the forces developed and shall accomodate the movements imparted to the building by the design ground motions. The foundation design criteria shall account for the dynamic nature of the seismic forces, the design ground motions and the design basis for strength and ductility of the structure.

Consideration shall be given to the manner in which the earthquake lateral force, computed in accordance with 780 CMR 1612.5 or 1612.6 will be transmitted from the soil or rock to the structure. Transmission of the lateral force will occur through one or more of the following foundation elements:

a. Lateral soil pressure against foundation walls, footings, grade beams and pile caps;

b. Lateral soil pressure against piles, piers or caissons;

c. Side or bottom friction on walls, footings or mats or;

d. Batter piles.

Bottom friction under pile caps shall be assumed to be ineffective in transmitting horizontal forces.

The horizontal force shall be distributed among the various elements in the foundation in proportion to their estimated rigidities. Any element which will participate in the transfer of horizontal forces from the soil to the structure shall be designed to resist forces in such a way that its ability to sustain static load will not be impaired.

1612.4.2 Site coefficient: The value of the site coefficient (S) shall be determined from Table 1612.4.1. In locations where the soil properties are not known in sufficient detail to determine the soil-profile type or where the soil profile does not fit any of the four types indicated in Table 1612.4.1, a site coefficient (S) of 1.5 shall be used. For determination of Site Coefficient, all soil and rock below the final ground surface shall be considered.

When a structure is located on soil deposits meeting the criteria for two or more site coefficient values, the largest applicable value shall be used.

Table 1612.4.1
SITE COEFFICIENT

Soil-profile type	Description [a,b]	Site Coefficient S
S_1	A profile consisting of: Rock of Material Classes 1 through 4, or; Rock of any characteristic, either shale-like or crystalline in nature, which has a shear wave velocity greater than 2,500 feet per second, or; Stiff soil conditions where the soil depth is less than 200 feet and the soil types overlying rock are stable deposits of weathered bedrock of Material Class 5; dense to very dense till, gravel or sand and gravel of Materials Classes 6 and 7; dense to very dense sand of Material Classes 8 and 9; dense inorganic silt of Material Class 9; stiff to hard clay of Material Class 10 with undrained shear strength of 2,000 pounds per square foot or greater, or; compacted granular fills provided that the fill soils are compacted throughout as required in 780 CMR 1804.1	1.0
S_2	A soil profile meeting the requirements for S_1 except the soil depth exceeds 200 feet; or a soil profile which contains up to 40 feet of medium stiff clay (Material Class 10), with undrained shear strength of 1,000 pounds per square foot or greater; or a soil profile which contains up to 40 feet of medium dense gravel, sand and/or silt (Material Classes 7 through 10), that is not susceptible to liquefaction in accordance with 780 CMR 1802.2	1.2
S_3	A soil profile containing 40 to 100 feet in thickness of medium stiff clay (Material Class 10) with undrained shear strength of 1,000 pounds per square foot or greater, with or without intervening layers of granular soils; or up to 40 feet of soft clay (Material Class 10) with undrained shear strength of less than 1,000 pounds per square foot; or up to 40 feet of very loose to loose gravel, sand or silt (Material Classes 7 through 9); or up to 20 feet of organic soil (Material Class 11) or loose or soft fill which was not placed in accordance with 780 CMR 1804.1	1.5
S_4	A soil profile containing more than 100 feet of medium stiff clay (Material Class 10) with undrained shear strength of 1,000 pounds per square foot or greater, with or without intervening layers of granular soils; or more than 40 feet of soft clay (Material Class 10) with undrained shear strength of less than 1,000 pounds per square foot; or more than 40 feet of very loose to loose sand or silt (Material Classes 8 and 9); or more than 20 feet of organic soil (Material Class 11); or more than 20 feet of loose or soft fill which was not placed in accordance with 780 CMR 1804.1; or more than 20 feet of soils of any type having a shear wave velocity of 500 feet per second or less.	2.0

Notes:
a) 1 foot = 304.8 mm
b) See appendix G for guidance in selecting Material Classes

1612.4.3 Soil-structure interaction: The design base shear, story shears, overturning moments and deflections determined by the requirements of 780 CMR 1612.5 or 1612.6 are permitted to be modified in accordance with approved procedures which account for the effects of soil-structure interaction.

1612.4.4 Structural framing systems: The basic structural framing systems to be utilized are indicated in Table 1612.4.4. Each type is subdivided by the types of vertical structural elements that will resist the design lateral forces. The structural system utilized shall be in accordance with the seismic performance category and height limitations indicated in Table 1612.4.4. The appropriate response modification factor (R) and the deflection amplification factor (C_d) indicated in Table 1612.4.4 shall be utilized in determining the base shear and the design story drift. Structural framing and seismic-resisting systems which are not contained in Table 1612.4.4 shall be permitted if analysis and test data are submitted that establish the dynamic characteristics and demonstrate the lateral force resistance and energy dissipation capacity to be equivalent to the structural systems listed in Table 1612.4.4 for equivalent response modification factor (R) values.

1612.4.4.1 Dual system: For a dual system, the moment frame shall be capable of resisting at least 25% of the design seismic forces. The total seismic force resistance is to be provided by the combination of the moment frame and the seismic-resisting elements in proportion to their rigidities.

1612.4.4.2 Combinations of framing systems: Different structural framing systems are permitted along the two orthogonal axes of the building. Combinations of framing systems shall comply with the requirements of 780 CMR 1612.4.4.2.1 and 1612.4.4.2.2

1612.4.4.2.1 Combination framing factor (R): The response modification factor (R) in the direction under consideration at any story shall not exceed the lowest response modification factor (R) obtained from Table 1612.4.4 or the seismic-resisting system in the same direction considered above that story.

Exception: Supported structural systems with weight equal to or less than 10% of the weight of the building are not required to comply with 780 CMR 1612.4.4.2.1.

1612.4.4.2.2 Combination framing detailing requirements: The detailing requirements of 780 CMR 1612.4.7 required by the higher response modification factor (R) shall apply to structural components common to systems having different response modification factors.

1612.4.4.3 Seismic Performance Category C: The structural framing system for buildings assigned to Seismic Performance Category C shall comply with the building height and structural system limitations in Table 1612.4.4.

1612.4.4.4 Seismic Performance Category D: The structural framing system for buildings assigned to Seismic Performance Category D shall comply with 780 CMR 1612.4.4.3 and the additional provisions of 780 CMR 1612.4.4.

1612.4.4.4.1 Limited building height: Buildings having a structural system of steel or cast-in-place concrete-braced frames or shear walls are limited to a height of 240 feet (73.15 m) where there are braced frames or shear walls so arranged that braced frames or shear walls in one plane resist not more than the following proportion of the seismic design force in each direction, including torsional effects:

1. 60% where the braced frame or shear walls are arranged only on the perimeter;
2. 40% where some of the braced frames or shear walls are arranged on the perimeter; or
3. 30% for other arrangements.

1612.4.4.4.2 Interaction effects: Moment-resisting frames that are enclosed or adjoined by more rigid elements not considered to be part of the seismic-resisting system shall be designed so that the action or failure of the enclosing or adjoining elements will not impair the vertical load and seismic force-resisting capability of the frame. The design shall provide for the effect of these rigid elements on the structural system at building deformations corresponding to the design story drift (delta) as determined in 780 CMR 1612.5.5.

TABLE 1612.4.4[(a)]
Structural Systems

	Basic Structural system Seismic Resisting System	Response Modification Factor (R)	Deflection Amplification Factor (Cd)	Structural system limitations and building height (feet) limitations (see Note b) Seismic Performace Category C	 D
1.	Loadbearing wall system Light-framed walls with shear panels	6½	4	Not limited	160
	Reinforced concrete shear walls	4 ½	4	Not limited	160
	Reinforced masonry shear walls	3½	3	Not limited	160
	Concentrically braced frames	3½	3½	Not limited	160
	Unreinforced masonry shear walls	1¼	1¼	Not permitted	Not permitted
	Plain concrete shear walls	1½	1½	Not permitted	Not permitted
2.	Building Frame System				
	Eccentrically braced frames, moment resisting connections at columns away from link beam	8	4	Not limited	160
	Eccentrically braced frames nonmoment-resisting connections at columns away from link beam	7	4	Not limited	160
	Light-framed walls with shear panels	7	4½	Not limited	160
	Concentrically braced frames	5	4½	Not limited	160
	Reinforced concrete shear walls	5½	5	Not limited	160
	Reinforced masonry shear walls	4½	4	Not limited	160
	Unreinforced masonry shear walls	1½	1½	Not permitted	Not permitted
	Plain concrete shear walls	2	2	Not permitted	Not permitted
3.	Moment-resisting frame system				
	Special moment frames of steel	8	5½	Not limted	Not limited
	Special moment frames of reinforced concrete	8	5½	Not limited	Not limited
	Intermediate moment frames of reinforced concrete	5	4½	Not limited	Not permitted
	Ordinary moment frames of steel	4½	4	Not limited	160
	Ordinary moment frame of reinforced concrete	3	2½	Not permitted	Not permitted
4.	Dual system with a special moment frame capable of resisting at least 25% of the prescribed seismic forces Eccentrically braced frames, moment-resisting connections at columns away from link beam	8	4	Not limited	Not limited
	Eccentrically braced frames, nonmoment-resisting connections at columns away from link beam	7	4	Not limited	Not limited
	Concentrically braced frames	6	5	Not limited	Not limited
	Reinforced concrete shear walls	8	6½	Not limited	Not limited
	Reinforced masonry shear walls	6½	5½	Not limited	Not limited
	Wood-sheathed shear walls	8	5	Not limited	Not limited
5.	Dual system with an intermediate moment frame of reinforced concrete or an ordinary moment frame of steel				

	Basic Structural system Seismic Resisting System	Response Modification Factor (R)	Deflection Amplification Factor (Cd)	Structural system limitations and building height (feet) limitations (see Note b) Seismic Performace Category	
				C	D
	capable of resisting at least 25% of the prescribed seismic forces				
	Concentrically braced frames	5	4½	Not limited	160
	Reinforced concrete shear walls	6	5	Not limited	160
	Reinforced masonry shear walls	5	4½	Not limited	160
	Wood-sheathed shear walls	7	4½	Not limited	160
6.	Inverted Pendulum structures Special moment frames of structural steel	2½	2½	Not limited	Not lmiited
	Special moment frames of reinforced concrete	2½	2½	Not limited	Not lmited
	Ordinary moment frames of structural steel	1¼	1¼	Not limited	Not permitted

Note a. Response modification factor(R) for application of 780 CMR 1612.5 and 1612.6: Deflection amplificaton factor (Cd) for application of 780 CMR 1612.5 and 1612.6.

Note b. The building height shall not exceed the general height limitation of 780 CMR 503.0 and 502.0 based on the type of construction

Note c. See 780 CMR 1612.4.4.4.1for description of building systems which are limited to buildings with a height of 240 feet or less.

Note d. See 780 CMR 1612.4.4.5 for description of building systems which are limited to buildings with a height of 160 feet or less.

1612.4.4.3.3 Deformational compatibility: Every structural component not included in the seismic force-resisting system in the direction under consideration shall be designed to be adequate for the vertical load-bearing capacity and the induced moments resulting from the design story drift (?) as determined in accordance with 780 CMR 1612.5.5 (see also 780 CMR 1612.4.8)

1612.4.4.4.4 Special moment frames: A special moment frame that is utilized but not required by Table 1612.4.4 is permitted to be discontinuous and supported by a more rigid system with a lower response modification factor (R) provided that the requirements of 780 CMR 1612.4.7.2.4 and 1612.4.7.4.2 are met. Where a special moment frame is required by Table 1612.4.4, the frame shall be continuous to the foundation.

1612.4.5 Building configuration: Buildings shall be classified as regular or irregular based on the plan and vertical configuration.

1612.4.5.1 Plan irregularity: Buildings having one or more of the features listed in Table 1612.4.5.1 shall be designated as having plan irregularity and shall comply with the requirements in the referenced code sections of Table 1612.4.5.1.

1612.4.5.2 Vertical irregularity: Buildings having one or more of the features listed in Table 1612.4.5.2 shall be designated as having vertical irregularity and shall comply with the requirements in the referenced code sections of Table 1612.4.5.2.

Exceptions:

1. Structural irregularities of Type 1 or 2 in Table 1612.4.5.2 do not apply where the

building story drift ratio is less than 130% of the story drift ratio of the next story above. Torsional effects are not required to be considered in the calculation of story drifts. The story drift ratio relationship for the top two stories of the building is not required to be evaluated.

2. IrregularityTypes 1 and 2 of Table 1612.4.5.2 are not required to be considered for one- and two-story buildings.

Table 1612.4.5.1
PLAN STRUCTURAL IRREGULARITIES

Irregularity type and description	Referenced Section	Seismic Performance Category Application
1 Torsional irregularity --- to be considered where diaphragms are rigid in relation to the vertical structural elements which resist the lateral seismic forces.	780 CMR 1612.4.7.4.2	D
Torsional irregularity shall be considered to exist where the maxixmum story drift com-puted, including accidental torsion, at one end of the structure transverse to an axis is more than 1.2 times the average of the story drifts at the two ends of the structure.	780 CMR 1612.5.3.1	C and D
2 Re-entrant corners		
Plan configurations of a structure and its lateral force-resisting system contain re-entrant corners, where both projections of the structure beyond a re-entrant corner are greater than 15% of the plan dimension of the structure in the given direction.	780 CMR 1612.4.7.4.2	D
3 Diaphragm discontinuity		
Diaphragms with abrupt discontinuities or variations in stifness, including those having cutout or open areas greater than 50% of the gross enclosed area of diaphragm, or changes in effective dia-phragm stiffness of more than 50% from one story to the next.	780 CMR 1612.4.7.4.2	D
4 Out-of-plane vertical element offsets		
Discontinuities in a lateral force-resistance path, such as out-of-plane offsets of the vertical elements which resist the lateral seismic forces.	780 CMR 1612.4.7.4.2	D
5 Nonparallel systems		
The vertical lateral force-resisting elements are not par-allel to, or are not symmetric about, the major orthogonal axes of the lateral force-resisting system.	780 CMR 1612.4.7.3.1	C and D

Table 1612.4.5.2
VERTICAL STRUCTURAL IRREGULARITIES

Irregularity type and description	Referenced Section	Seismic Performance Category Application
1 Stiffness irregularity --- soft story.		
A soft story is one in which the lateral stiffness is less than 70% of that in the story above or less than 80% of the average stiffness of the three stories above.	780 CMR 1612.4.6.2	D
2 Weight (mass) irregularity		
Mass irregularity shall be considered to exist where the effective masss of any story is more than 150% of the effective mass of an adjacent story. A roof that is lighter than the floor below is not required to be considered.	780 CMR 1612.4.6.2	D
3 Vertical geometric irregularity		
Vertical geometric irregularity shall be considered to exist where the horizontal dimension of the lateral force-resisting system in any story is more than 130% of that in an adjacent story.	780 CMR 1612.4.6.2	D
4 In-plane discontinuity in vertical lateral force-resisting elements.		
An in-plane offset of the lateral force-resisting elements greater than the length of those elements.	780 CMR 1612.4.7.4.2	D
5 Discontinuity in capacity --- weak story		
A weak story is one in which the story lateral strength is less than 80% of that in the story above. The story strength is the total strength of all seismic resisting elements sharing the story shear for the direction under consideration.	780 CMR 1612.4.7.2.4	C and D

1612.4.6 Analysis procedures: A structural analysis shall be made for all buildings in accordance with the requirements of 780 CMR 1612.4.6. An alternative generally accepted procedure, including utilization of a site-specific response spectrum, is permitted, where approved by the code official. The limitations on the base shear in 780 CMR 1612.6 apply to dynamic modal analysis. When this alternative is used, the site specific response spectrum shall be considered in the required peer review.

1612.4.6.1 Seismic Performance Category C: Regular or irregular buildings assigned to Category C shall be analyzed in accordance with the procedures in 780 CMR 1612.5.

1612.4.6.2 Seismic Performance Category D: Buildings assigned to Seismic Performance Category D shall be analyzed in accordance with the referenced sections in Table 1612.4.6.2.

Table 1612.4.6.2
ANALYSIS PROCEDURES FOR SEISMIC PERFORMANCE CATEGORY D

Building Description	Referenced Section and Procedures
1 Buildings designated as regular which do not exceed 240 feet in height.	780 CMR 1612.5
2 Buildings that have only vertical irregularities of Type 1, 2 or 3 in table 1612.4.5.2 and have a height exceeding five stories or 65 feet, and all buildings exceeding 240 feet in height.	780 CMR 1612.6
3 All other buildings designated as having plan or vertical irregularities in accordance with tables 1612.4.5.1 and 1612.4.5.2	780 CMR 1612.5 or 780 CMR 1612.6

1612.4.7 Design, detailing requirements and structural component load effects: The design and detailing of structural components of the seismic-resisting system shall comply with the requirements of 780 CMR 1612.4. Foundation design shall conform to the applicable requirements of 780 CMR 18.

1612.4.7.1 Seismic Performance Category A: The design and detailing of buildings assigned to Seismic Performance Category A shall comply with the requirements of 780 CMR 1612.4.7.1.

1612.4.7.1.1 Ties and continuity: Except for connections exempted by 780 CMR 1612.7, all parts of the building that transmit seismic force shall be interconnected to form a continuous path to the building's seismic-resisting system. Any smaller portion of the building shall be tied to the remainder of the building with elements having a strength capable of transmitting the seismic force (F_p) determined in accordance with 780 CMR 1612.7, but not less than one-third of the effective peak velocity-related acceleration (A_v) times the weight of the smaller portion (W_c) or 5% of the portion's weight. whichever is greater. For a building which is exempt from a full seismic analysis by 780 CMR 1612.2 and is only required to comply with 780 CMR 1612.4.7.1, the building's main windforce-resisting system in accordance with 780 CMR 1611.0 shall be deemed to be the seismic-resisting system. A positive connection for resisting a horizontal force acting parallel to the member shall be provided for each beam, girder or truss to its support. The connection shall have a minimum strength of 5% of the dead plus *live load* reaction.

1612.4.7.1.2 Concrete or masonry wall anchorage: Concrete and masonry walls shall be anchored to the roof and all floors that provide lateral support for the wall. The anchorage shall provide a direct connection between the walls and the roof or floor construction. Toe nailing or nails subject to withdrawal forces is not permitted. Wood ledgers shall not be subjected to cross-grain bending or cross-grain tension. The connections shall be capable of resisting a lateral seismic force (F_p) in accordance with either 780 CMR 1612.4.7.2.8 or 780 CMR 1612.7, for loadbearing and nonloadbearing walls respectively, but not less than 1,000 times the effective peak velocity-related acceleration (A_v) (pounds) per lineal foot of wall. Walls shall be designed to resist bending between anchors where the anchor spacing exceeds four feet (1.22 m).

1612.4.7.2 Seismic Performance Category B: Buildings assigned to Category B shall conform to the requirements of 780 CMR 1612.4.7.1 for Category A and the requirements of 780 CMR 1612.4.7.2.

1612.4.7.2.1 Component Load Effects: Seismic load effects on components shall be detemined from the load analysis as required by 780 CMR 1612.4.6, by other portions of 780 CMR 1612.4.7.2, and by 780 CMR 1616. The second order effects shall be included where applicable. Where these seismic load effects exceed the minimum load path connection forces given in 780 CMR 1612.4.7.1.1 and 1612.4.7.2.2, they shall govern.

1612.4.7.2.2 Openings: Where openings occur in shear walls, diaphragms or other plate-type elements, the edges of the openings shall be designed to transfer the stresses into the structure. The edge reinforcement shall extend into the body of the wall or diaphragm a distance sufficient to develop the stress of the edge reinforcement member.

1612.4.7.2.3 Orthogonal effects: The design seismic forces shall be applied separately, and independently, in each of two orthogonal directions.

1612.4.7.2.4 Discontinuities in vertical system: Buildings with a discontinuity in lateral capacity, vertical irregularity Type 5 as defined in Table 1612.4.5.2, shall not be more than two stories or 30 feet (9.14 m) in height where the "weak" story has a calculated strength of less than 65% of the storey above.

Exception: Where the "weak" story is capable of resisting a total seismic force equal to 75% of the deflection application factor (Cd) times the design force prescribed in 780 CMR 1612.5.

1612.4.7.2.5 Nonredundant systems: The building design shall compIy with 780 CMR 1604.2.

1612.4.7.2.6 Collector elements: Collector elements shall be provided which are capable of transferring the seismic forces originating in other portions of the building to the element providing the resistance to those forces.

1612.4.7.2.7 Diaphragms: The deflection in the plane of the diaphragm. as determined by engineering analysis, shall not exceed the allowable deflection of the attached elements. Allowable deflection shall be that deflection which will permit the attached element to maintain its structural integrity under the individual loading and continue to support the prescribed *loads*.

Floor and roof diaphragms shall be designed to resist the following seismic forces: a minimum force equal to 50% the effective peak velocity-related acceleration (A_V) times the weight of the diaphragm and other elements of the building attached thereto, plus the portion of the seismic shear force at that level (V_X) required to be transferred to the components of the vertical seismic-resisting system because of offsets or changes in stiffness of the vertical components above and below the diaphragm.

Diaphragms shall provide for both the shear and bending stresses resulting from these forces. Diaphragms shall have ties or struts to distribute the wall anchorage forces into the diaphragm. Connections within diaphragms, connections of diaphragms to lateral load resisting elements, and connections of collectors such as ties and struts, to the diaphragm and vertical elements, shall be positive connections, mechanical or welded.

1612.4.7.2.8 Loadbearing walls: Exterior and interior loadbearing walls and their anchorage shall bc designed for a force of the effective peak velocity-related acceleration (A_V) times the weight of wall, normal to the surface, with a minimum force of 10% of the weight of the wall. Interconnection of wall elements and connections to supporting framing systems shall have sufficient ductility, rotational capacity or sufficient strength to resist shrinkage, thermal changes and differential foundation settlement where combined with seismic forces. The connections shall also satisfy 780 CMR 1612.4.7.1.2

1612.4.7.2.9 Inverted pendulum-type structures: Supporting columns or piers of inverted pendulum-type structures shall be designed for the bending moment calculated at the base determined by the procedures given in 780 CMR 1612.5 and shall vary uniformly to a moment at the top equal to one-half the calculated bending moment at the base.

1612.4.7.2.10 Anchorage of Nonstructural Systems: When required by 780 CMR 1612.7, all portions or components of the building shall be anchored for the seismic force (Fp) prescribed therein.

1612.4.7.3 Seismic Performance Category C: Buildings assigned to Category C shall conform to the requirements of 780 CMR 1612.4.7.2 for Category B and the requirements of 780 CMR 1612.4.7.3.

1612.4.7.3.1 Plan irregularity: Buildings that have plan structural irregularity Type 5 in Table 1612.4.5.1 shall be analyzed for the critical *load* effect due to direction of application of seismic forces. Alternatively, the building shall be analyzed in any two orthogonal directions. Structural elements and foundations shall be designed for 100% of the forces for one direction plus a simultaneous load of 30% of the forces for the perpendicular direction, except where the amplified seismic load effects of 780 CMR 1616.4 are used.

1612.4.7.4 Seismic Performance Category D: Buildings assigned to Category D shall conform to the requirements of 780 CMR 1612.4.7.3 for Category C and to the requirements of 780 CMR 1612.4.7.4.

1612.4.7.4.1 Orthogonal load effects: Buildings shall be designed for 100% of the seismic forces for one direction plus a simultaneous *load* of 30% of the seismic forces for the perpendicular direction. The load combination requiring the maximum structural component strength shall be used.

Exception: Where amplified seismic load effects of 780 CMR 1616.4 are used, the building may be designed for the load effects based on analyses in any two orthogonal directions. Diaphragms and components of the seismic-resisting system utilized in only one of the two orthogonal directions are not required to be designed for the combined *load* effects.

1612.4.7.4.2 Plan or vertical irregularities: For buildings having a plan irregularity of Type 1, 2, 3 or 4 in Table 1612.4.5.1 or a vertical irregularity of Type 4 in Table 1612.4.5.2, the design forces determined from 780 CMR 1612.5 shall be increased 25% for connections of diaphragms to vertical elements and to collectors and for connections of collectors to the vertical elements.

1612.4.7.4.3 Vertical seismic loads: The vertical component of earthquake ground motion shall be accounted for in the design of horizontal cantilever and horizontal prestressed components. Horizontal prestressed components shall be designed for load combination #8 of 780 CMR 1616.3.1, including the amplified seismic effects of 780 CMR 1616.4. Horizontal cantilever structural components shall be designed for a net upward force of 0.2 times the *dead load*, as a separate loading case, in addition to the applicable load combinations of 780 CMR 1616.

1612.4.8 Deflection and drift limits: The design story drift (?) as determined in 780 CMR 1612.5.5 or 1612.6.8, shall not exceed the allowable story drift (?$_a$) from Table 1612.4.8 for any story. For structures with significant torsional deflections, the maximum drift shall include torsional effects. The total deflection of a building due to seismic design forces shall not encroach on an interior lot line. All portions of the building shall be designed and constructed to act as an integral unit in resisting seismic forces unless separated structurally by a distance sufficient to avoid contact causing damage to the structural system of the building under total deflection (d_x) as determined by 780 CMR 1612.5.5.1.

1612.4.9 Foundation walls and retaining walls: Exterior foundation walls and retaining walls shall be designed to resist at least the superimposed effects of the total static lateral soil pressure, excluding the pressure caused by any temporary surcharge, plus and earthquake force of $0.045Y_t\,H^2$ for horizontal backfill surface. Where Y_t is the total unit weight of the soil and H is the height of the wall measured as the difference in elevation of finished ground surface (or floor) in front of and behind the wall. Surcharges which are applied over extended periods of time shall be included in the total static lateral soil pressure and their earthqake lateral force shall be computed and added to the force of $0.045Y_t\ H^2$. The earthquake force from the backfill shall be distributed as an inverse triangle over the height of the wall. The point of application of the earthquake force from an extended duration surcharge shall be determined on an individual case basis. If the backfill consists of loose saturated granular soil, consideration shall be given to the potential increase in lateral pressure due to liquefaction of the backfill during the seismic loading in accordance with 780 CMR 1805.2. For use in wall strength design, a load factor of 1.43 times the earthquake force calculated above shall be applied.

1612.5 Equivalent lateral force procedure: 780 CMR 1612.5 provides requirements for the equivalent lateral force procedure of seismic analysis of buildings. For purposes of analysis, the building is considered to be fixed at the base. See 780 CMR 1612.4.6 for limitations on the applicability of this procedure.

Table 1612.4.8

ALLOWABLE STORY DRIFT (?$_a$) [a]

Building	Seismic Hazard Exposure Group		
	I	II	III
One story buildings without equipment attached to the seismic-resisting structural system and with interior walls, partitions, ceilings and exterior wall systems which have been designed to accomodate the story drifts.	No Limit	$0.020\ h_{sx}$	$0.015\ h_{sx}$
Buildings having four stories or less with interior walls, partitions, ceilings and exterior wall systems which have been designed to accomodate the story drifts.	$0.025\ h_{sx}$	$0.020\ h_{sx}$	$0.015\ h_{sx}$
All other buildings	$0.020\ h_{sx}$	$0.015\ h_{sx}$	$0.010\ h_{sx}$

Note a: h_{sx} is the story height below level x

1612.5.1 Seismic base shear: The seismic base shear (V) in a given direction shall be determined in accordance with the following formula:

$$V = C_s W$$

where:

C_S = The seismic design coefficient determined in accordance with 780 CMR 1612.5.1.1.

W = The total *dead load* and applicable portions of other *loads* listed below:

1. For occupancies in Use Group S, a minimum of 25% of the floor *live load* shall be applicable.

Exception: Floor *live load* in public garages and open parking structures is not applicable.

2. Where partitions will be present, whether or not partitions are shown on the *construction documents*, the actual partition weight or a minimum weight of 10 psf of floor area, whichever is greater, shall be applicable.
3. Total operating weight of permanent equipment.
4. Snow load reduction of 50% is permitted.

1612.5.1.1 Calculation of seismic coefficient (C_S): The seismic design coefficient (C_S) shall be determined in accordance with the following formulas:

$$C_s = \frac{1.2\, A_v\, S}{RT^{-}}$$

where:

A_v = The coefficient representing effective peak velocity-related acceleration from 780 CMR 1612.2.3.
S = The coefficient for the soil-profile characteristics of the site in Table 1612.4.1.
R = The response modification factor in Table 1612.4.3.
T = The fundamental period of the building determined in 780 CMR 1612.5.1.2.

A soil-structure interaction reduction is permitted where determined from an approved procedure. Alternatively, the seismic design coefficient (C_S) is not required to be greater than the following equation:

$$C_s = \frac{2.5\, A_a}{R}$$

where:

A_a = The seismic coefficient representing the effective peak acceleration as determined in 780 CMR 1612.2.3
R = The response modification factor in Table 1612.4.4

1612.5.1.2 Period determination: The fundamental period (T), in seconds, of the building, in the direction under consideration, shall be established based on the structural properties and deformational characteristics of the resisting elements in a properly substantiated analysis. The fundamental period (T) shall not exceed the product of the coefficient for the upper limit on calculated period (C_a) from Table 1612.5.1.2, and the approximate fundamental period (T_a).

Alternatively, the fundamental period (T) shall be determined from 780 CMR 1612.5.1.2.1.

Table 1612.5.1.2
COEFFICIENT FOR UPPER LIMIT ON CALCULATED PERIOD (C_a)

Av Coefficient representing effective peak velocity related acceleration	Ca
0.12	1.6

1612.5.1.2.1 Approximate fundamental period (T_a): The approximate fundamental period (T_a), in seconds, shall be determined from the following formula:

$$T_a = C_T H_n^{3/4}$$

where:

h_n = The height (in feet) from the base to the highest level of the building.
C_T = 0.035 For moment-resisting frame systems of steel which provide 100% of the required lateral force resistance,

where the frame is not enclosed or adjoined by more rigid components.

$C_T =$ 0.03 For moment-resisting frame systems of concrete which provide 100% of the required lateral force resistance, where the frame is not enclosed or adjoined by more rigid components.

$C_T =$ 0.03 For building frame systems with an eccentrically braced steel frame or dual systems with an eccentrically braced frame.

$C_T =$ 0.02 For seismic-resisting systems with shear walls, shear panels or concentrically braced frames and all other building systems.

Alternatively, the approximate fundamental period *(T_a)*, in seconds, shall be determined from the following formula for buildings in which the lateral force-resisting system consists of concrete or steel moment-resisting frames capable of resisting 100% of the required lateral force and where such frames are not enclosed or adjoined by more rigid components tending to prevent the frames from deflecting when subjected to seismic forces. Such buildings shall not exceed 12 stories in height and shall have a story height of not less than ten feet (3048 mm).

$$T_s = 0.1N$$

where:

$N =$ Number of stories.

1612.5.2 Vertical distribution of seismic forces: The lateral force *(F_x)* induced at any level shall be determined from the following formulas:

$$F_x = C_{vx} V$$

$$C_{vx} = \frac{w_x h_x^k}{\sum_{i=1}^{n} w_i h_i^k}$$

where:

C_{vx} = Vertical distribution factor

V = Total design lateral force or shear at the base of the building

w_i and w_x = the portion of the total gravity load of the building (W) located or assigned to level i or x

h_i and h_x = the height (in feet) from the base to level i or x

k = An exponent related to the building period as follows;
For buildings having a period of 0.5 seconds or less, k=1.
For buildings having a period of 2.5 seconds or more, k=2
For buildings having a period between 0.5 and 2.5 seconds, k shall be 2 or shall be determined by linear interoplation between 1 and 2.

1612.5.3 Horizontal shear distribution: The seismic design story shear in any story (V_x) shall be determined from the following formula:

$$V_x = \sum_{i=x}^{n} F_i$$

where:

F_i = the portion of the seismic base shear (*V*) induced at level *i*.

The seismic design story shear (*V_x*) shall be distributed to the various vertical elements of the seismic-resisting system in the story under consideration based on the relative lateral stiffness of the vertical resisting elements and the diaphragm.

1612.5.3.1 Torsion: The design shall include the torsional moment (M_t) resulting from the location of the building masses plus the accidental torsional moments (M_{ta}) caused by assumed displacement of the mass each way from its actual location by a distance equal to 5% of the dimension of the building perpendicular to the direction of the applied forces.

In buildings of Seismic Performance Categories C, D and E, where Type 1 torsional irregularity exists as defined in Table 1612.4.5.1, the effects shall be accounted for by increasing the accidental torsion at each level by a torsional amplification factor (A_X) determined from the following formula:

$$A_x = \left(\frac{\delta_{max}}{1.2\,\delta_{avg}}\right)^2$$

where:

d_{max} = the maximum displacment at level *x*.

d_{avg} = the average of the displacments at the extreme points of the structure at level *x*.

The torsional amplification factor (A_X) is not required to exceed 3.0.

1612.5.4 Overturning: The building shall be designed to resist overturning effects caused by the seismic forces determined in 780 CMR 1612.5.2. At any story, the increment of overturning moment in the story under consideration shall be distributed to the various vertical resisting elements in the same proportion as the distribution of the horizontal shears to those elements.

The overturning moments at level x (M_X) shall be determined from the following formula:

$$M_x = \tau \sum_{i=x}^{n} F_i\left(h_i - h_x\right)$$

where:

F_i = The portion of the seismic base shear (*V*) induced at level *i*.

h_i and h_X = The height (in feet) from the base to level *i* or *x*.

t = 1.0 for the top ten stories;
0.8 for the 20th story from the top and below; and
a value between 1.0 and 0.8 determined by a straight line interpolation for stories between the tenth and 20th stories below the top.

The foundations of buildings, except inverted pendulum structures, shall be designed for the foundation overturning design moment (M_f) at the foundation-soil interface determined by the equation for the overturning moment at level *x* (M_X) with an overturning moment reduction factor (t) of 0.75 for all building heights.

1612.5.5 Drift determination and P-delta effects: Story drifts and, where required, member forces and moments due to P-delta effects, shall be determined in accordance with 780 CMR 1612.5.5.1 and 1612.5.5.2.

1612.5.5.1 Story drift determination: The design story drift (Δ) shall be computed as the difference of the deflections at the top and bottom of the story under consideration. The deflections of level x at the center of the mass (d_X) shall be determined in accordance with the following formula:

$$\delta_x = C_d\,\delta_{xe}$$

where:

C_d = The deflection amplification factor in Table 1612.4.4.

d_{xe} = The deflections determined by an elastic analysis.

The elastic analysis of the seismic-resisting system shall be made utilizing the required seismic design forces of 780 CMR 1612.5.2.

For determining compliance with the story drift limitation of 780 CMR 1612.4.8, the deflection of level x at the center of mass (d_X) shall be calculated as required in this section. For the purposes of this drift analysis only, the computed fundamental period (T) of the building is not required to include the upper bond limitation specified in 780 CMR 1612.5.1.2 when determining drift level seismic design forces.

Where applicable, the design story drift (?) shall be increased by the incremental factor relating to the P-delta effects as determined in 780 CMR 1612.5.5.2.

1612.5.5.2 P-delta effects: P-delta effects on story shears and moments, the resulting member forces and moments, and the story drifts induced by these effects are not required to be considered where the stability coefficient (?), as determined by the following formula, is equal to or less than 0.10:

$$? = \frac{P_x -}{V_s h_{sx} C_d}$$

where:

P_x = The total vertical design load at story level x. In calculating the vertical design load for the purpose of determining P-delta effects, individual load factors are not required to exceed 1.0.

? = The design story drift occurring simultaneously with the story shear (V_X)

V_x = The seismic shear force between levels x and x-1.

h_{sx} = The story height below level x.

C_d = The deflection amplification factor in Table 1612.4.4

The stability coefficient (?) shall not exceed $?_{max}$ determined as follows:

$$?_{max} = \frac{0.5}{? \ C_d} \ ? \ 0.25$$

where:

ß = The ratio of shear demand to shear capacity for the story between levels x and x-1. This ratio is permitted to be considered as 1.0.

Where the stability coefficient (?) is greater than 0.10 but less than or equal to $?_{max}$, the incremental factor related to P-delta effects shall be determined by rational analysis. To obtain the story drift for including the P-delta effect, the design story drift determined in 780 CMR 1612.5.5.1 shall be multiplied by 1.0/(1 - ?).

1612.6 Modal analysis procedure: 780 CMR 1612.6 provides required standards for the modal analysis procedure of seismic analysis of buildings. 780 CMR 1612.4.6 specifies the limitations on the applicability of this procedure.

1612.6.1 General: The symbols in this method of analysis have the same meaning as those for similar terms used in 780 CMR 1612.5, with the subscript "m" denoting quantities in the mth mode.

1612.6.2 Modeling: The building shall be modeled as a system of masses lumped at the floor levels with each mass having one degree of freedom; lateral displacement in the direction under consideration.

1612.6.3 Modes: The analysis shall include, for each of two mutually perpendicular axes, at least the lowest three modes of vibration, or all modes of vibration with periods greater than 0.4 seconds, or sufficient modes to include 90% of the participating mass of the structure, whichever is greater. The number of modes shall equal the number of stories for buildings less than three stories in height.

1612.6.4 Periods: The required periods and mode shapes of the building in the direction under consideration shall be calculated by established methods of structural analysis for the fixed base condition utilizing the masses and elastic stiffnesses of the seismic-resisting system.

1612.6.5 Modal base shear: The portion of the base shear contributed by the m^{th} mode (V_m) shall be determined from the following formula:

$$V_m = C_m W_m$$

where:

C_{sm} = The modal seismic design coefficient determined by the following formula.

W_m = The effective modal gravity load determined by the following formula.

$$W_m = \frac{\left(\sum_{i=1}^{n} W_i ?_{im} \right)^2}{\sum_{i=1}^{n} W_i ?^2_{im}}$$

where:

w_i = the portion of the total gravity load of the building at level i.

$?_{im}$ = The displacement amplitude at the ith level of the building when vibrating in its mth mode.

The modal seismic design coefficient (C_{sm}) shall be determined in accordance with the following formula:

$$Cm = \frac{1.2\, A_v S}{R T^{-}_{m}}$$

where:

A_v = Seismic coefficient representing the effective peak velocity-related acceleration as determined in 780 CMR 1612.2.3.

S = The coefficient for the soil-profile characteristics of the site as determined by Table 1612.4.1.

R = The response modification factor determined from Table 1612.4.4.

T_m = The modal period of vibration, in seconds, of the mth mode of the building.

The modal seismic design coefficient (C_{sm}) is not required to exceed 2½ times the seismic coefficient representing the effective peak acceleration (A_a) divided by the response modification factor (R).

Exceptions:

1. The limiting value of the modal seismic design coefficient (C_{sm}) is not applicable to Category D and E buildings with a period of 0.7 seconds or greater located on type S_4 soils.
2. For buildings on soil-profile characteristics S_3 or S_4, the modal seismic design coefficient (C_{sm}) for modes other than the fundamental mode that have periods less than 0.3 seconds is permitted to be determined by the following formula:

$$C_{sm} = \frac{A_a (1.0 + 5.0\, T_m)}{R}$$

3. For buildings where any modal period of vibration (T_m) exceeds 4.0 seconds, the modal seismic design coefficient (C_{sm}) for that mode is permitted to be determined by the following formula:

$$C_{sm} = \frac{3\, A_v S}{R T_m^{4/3}}$$

where:

A_a = Seismic coefficient representing the effective peak acceleration as determined in 780 CMR 1612.2.3.

A_v = Seismic coefficient representing the effective peak velocity-related acceleration as determined in 780 CMR 1612.2.3.

R = The response modification factor determined from Table 1612.4.4.

T_m = The modal period of vibration, in seconds, of the mth mode of the building.

S = The coefficient for the soil profile characteristics of the site as determined by Table 1612.4.1.

1612.6.6 Modal forces, deflections and drifts:

The modal force (F_{xm}) at each level shall be determined by the following formulas:

$$F_{xm} = C_{vxm} V_m$$

$$C_{vxm} = \frac{w_x ?_{xm}}{\overset{n}{\underset{i=1}{?}} W_i ?_{im}}$$

where:

C_{vxm} = The vertical distribution factor in the m^{th} mode.

V_m = The total design lateral force or shear at the base in the m^{th} mode.

w_i and w_x = The portion of the total gravity load of the building (W) located or assigned to level i or x.

$?_{xm}$ = The displacement amplitude at the x^{th} level of the building when vibrating in the m^{th} mode.

$?_{im}$ = The displacement amplitude at the i^{th} level of the building when vibrating in the m^{th} mode.

The modal deflection at each level (d_{xm}) shall be determined by the following formulas:

$$?_{xm} = C_d ?_{xem}$$

$$?_{xem} = ?\frac{g}{4?^2}? ?\frac{T_m^2 F_{xm}}{W_x}?$$

where:

C_d = The deflection amplification factor determined from Table 1612.4.4.

d_{xem} = The deflection of level x in the m^{th} mode at the center of the mass at level x determined by an elastic analysis.

g = The acceleration due to gravity (feet per $second^2$).

T_m = The modal period of vibration, in seconds, of the m^{th} mode of the building.

F_{xm} = The portion of the seismic base shear in the m^{th} mode, induced at level x.

w_x = The portion of the total gravity load of the building (W) located or assigned to level x.

The modal drift in a story ($?_m$) shall be computed as the difference of the deflections (d_{xm}) at the top and bottom of the story under consideration.

1612.6.7 Modal story shears and moments: The story shears, story overturning moments. and the shear forces and overturning moments in walls and braced frames at each level, due to the seismic forces determined from the appropriate equation in 780 CMR 1612.6.6, shall be computed for each mode by linear static methods.

1612.6.8 Design values: The design value for the modal base shear (V_t), each of the story shear, moment and drift quantities, and the deflection at each level shall be determined by combining their modal values, obtained from 780 CMR 1612.6.6 and 1612.6.7. The combination shall be determined by taking the square root of the sum of the squares of each of the modal values (SRSS method) or by using the Complete Quadratic Combination (CQC) method. When the periods of any two modes used in this analysis differ by less than 25% the CQC method shall be used.

The base shear (V) utilizing the equivalent lateral force procedure in 780 CMR 1612.5 shall be calculated based on a fundamental period of the building (T), in seconds, of 1.2 times the coefficient for the upper limit on the calculated period (C_a) times the approximate fundamental period of the building (T_a). Where the design value for the modal base shear (V_t) is less than the calculated base shear (V) utilizing the equivalent lateral force procedure, the design story shears, moments, drifts and floor deflections shall be multiplied by the following modification factor:

$$\frac{V}{V_t}$$

where:

V = The equivalent lateral force procedure base shear, calculated in accordance with 780 CMR 1612.6 and 780 CMR 1612.5.

V_t = The modal base shear, calculated in accordance with 780 CMR 1612.6

The model base shear (V_t) is not required to exceed the base shear from the equivalent lateral force procedure in 780 CMR 1612.5

1612.6.9 Horizontal shear distribution: The distribution of horizontal shear shall be in accordance with the requirements of 780 CMR 1612.5.3.

1612.6.10 Foundation overturning: The foundation overturning moment at the foundation-soil interface shall not be reduced by more than 10%.

1612.6.11 P-delta effects: The P-delta effects shall be determined in accordance with 780 CMR 1612.5.5.2. The story drifts and story shears shall be determined in accordance with 780 CMR 1612.6.8.

1612.7 Architectural, mechanical and electrical components and systems: All components and systems in buildings shall be designed and constructed to resist seismic forces as determined in accordance with the provisions of 780 CMR 1612.7. Architectural, mechanical and electrical components and systems in buildings assigned to Seismic Hazard Perfrmance Category C, and are in Seismic Hazard Exposure Group I and have a Performance Criteria Factor of 0.5, are exempt from the requirements of 780 CMR 1612.7.

Exceptions:

1. Individual electrical and mechanical components which weigh more than 2,000 pounds and are located more than 15 feet above the base shall be designed in accordance with 780 CMR 1612.7.4.
2. Elevator components and systems in buildings assigned to Seismic Hazard Performance Category C and are in Seismic Hazard Exposure Group I buildings not more than 70 feet in height are exempt from the requirements of 780 CMR 1612.7.

1612.7.1 Component force application: The component seismic force shall be applied at the center of gravity of the component nonconcurrently in any horizontal direction. Mechanical and electrical components and systems shall be designed for a nonsimultaneous vertical force of 33% of the horizontal force.

1612.7.2 Component force transfer: Components shall be attached such that the component forces are transferred to the structural system of the building. Component seismic attachments shall be positive connections without consideration of frictional resistance.

1612.7.3 Architectural component design: Architectural components and their attachments shall be designed for seismic forces (F_p) determined in accordance with the following formula:

$$F_p = A_v C_c P W_c$$

where:

A_v = The coefficient representing effective peak velocity-related acceleration from 780 CMR 1612.2.3.

C_c = The seismic coefficient for architectural components from Table 1612.7.3.

P = Performance criteria factor from Table 1612.7.3.

W_c = The weight of the architectural component.

1612.7.3.1 Exterior wall panel connections: The connections of exterior wall panels to the building seismic-resisting system shall be designed for the design story drift determined in accordance with 780 CMR 1612.5.5.1 or in accordance with 780 CMR 1612.6.6 and 1612.6.8.

1612.7.3.2 Architectural component deformation: Architectural components shall be designed for the design story drift of the structural seismic-resisting system determined in accordance with 780 CMR 1612.5.5.1 or in accordance with 780 CMR 1612.6.6 and 1612.6.8. Architectural components shall be designed for vertical deflection due to joint rotation of cantilever structural members.

Exception: Architectural components having a performance criteria factor of 0.5 shall be designed for 50% of the design story drift.

1612.7.3.3 Ceilings: Provision shall be made for the lateral support and interaction of other architectural, mechanical and electrical systems or components incorporated into the ceiling which impose seismic forces into the ceiling system.

Table 1612.7.3
ARCHITECTURAL COMPONENT SEISMIC COEFFICIENT (C_c) AND PERFORMANCE CRITERIA FACTOR (P)[a]

	Architectural Component	Component Seismic Coefficient (C_c)	Performance Criteria Factor (P) Seismic Hazard Exposure Group I	II	III
1	Exterior nonloadbearing walls[b]	0.9	1.5	1.5	1.5
2	Interior nonloadbearing walls[b],				
	Exit, stair and elevator enclosures.	1.5	1.0	1.0	1.5
		0.9	1.0	1.0	1.5
	Other vertical shaft enclosures Other nonloadbearing walls	0.9	1.0	1.0	1.5
3	Cantilever elements; parapets, chimneys or stacks	3.0	1.5	1.5	1.5
4	Wall attachments	3.0	1.5	1.5	1.5
5	Veneer connections	3.0	0.7	1.0	1.0
6	Penthouses[c]	0.6	0.7	1.0	1.0
7	Membrane fire protection	0.9	1.0	1.0	1.5
8	Ceilings				
	Fireresistance rated membrane	0.9	1.0	1.0	1.5
	Nonfireresistance rated membrane	0.6	0.5	1.0	1.0
9	Storage racks, contents included	1.5	1.0	1.0	1.5
10	Access floor, supported equipment included	2.0	0.5	1.0	1.5
11	Elevator and counterweight guardrails and supports	1.25	1.0	1.0	1.5

Note a: See 780 CMR 1612.7 for general exceptions
Note b: See 780 CMR 1612.4.7.2.8 for exterior and interior loadbearing wall requirements
Note c: The design seismic force for a penthouse shall be the larger of the force determined in accordance with 780 CMR 1612.7.3, this table and the force determined in accordance with 780 CMR 1612.5 or 1612.6

1612.7.4 Mechanical, electrical component and system design: Mechanical, electrical components and systems and their attachments shall be designed for seismic forces (F_p) determined in accordance with the following formula:

$$F_p = A_v C_c P a_c W_c$$

where:

A_v = The coefficient representing effective peak velocity-related acceleration from 780 CMR 1612.2.3.

C_c = The seismic coefficient for mechanical, electrical components and systems from Table 1612.7.4(1).

P = Performance criteria factor from 1612.7.4(1).

a_c = The attachment amplification factor determined in accordance with Table 1612.7.4(2).

W_C = The operating weight of the mechanical, electrical component or system.

Alternatively, the seismic forces (F_p) shall be determined by a properly substantiated dynamic analysis subject to approval.

Exception: Bracing of fire sprinkler systems shall be permitted to be in accordance with NFiPA 13 listed in ***Appendix A***.

Table 1612.7.4(1)
MECHANICAL, ELECTRICAL COMPONENT AND SYSTEM SEISMIC COEFFICIENT (C_c) AND PERFORMANCE CRITERIA FACTOR (P)[a]

Mechanical, electrical component or system	Component or system seismic coefficient (C_C)	Performance Criteria Factor (P) Sesimic Hazard Exposure Group I	II	III
1 Fire protection equipment and systems	2.0	1.5	1.5	1.5
2 Emergency or standby electrical systems	2.0	1.5	1.5	1.5
3 Elevator drive, suspension system and controller anchorage	1.25	1.0	1.0	1.5
4 General equipment				
A. Boilers, furnaces, incinerators, water heaters and other equip-ment utilizing combustible energy sources or high temper-ature sources.				
B. Communication systems				
C. Electrical bus ducts and primary cable systems[b].	2.0	0.5	1.0	1.5
D. Electrical motor control cen-ters, motor control devices, switchgear, transformers and unit substations.				
E. Reciprocating or rotating equipment				
F. Tanks, heat exchangers and pressure vessels.				
5 Manufacturing and process machinery	0.67	0.5	1.0	1.5
6 Pipe systems				
Gas and high hazard piping	2.0	1.5	1.5	1.5
Fire suppression piping	2.0	1.5	1.5	1.5
Other pipe systems[c]	0.67	0.5	1.0	1.5
7 HVAC ducts[d]	0.67	0.5	1.0	1.5
8 Electrical panel board	0.67	0.5	1.0	1.5
9 Lighting fixtures[e]	0.67	0.5	1.0	1.5

Note a: See 780 CMR 1612.7 for general exceptions

Note b: Electrical conduit seismic restraints are not required for any one of the following conditions

1. Conduit suspended by individual hangars 12 inches or less in length from the top of the conduit to the supporting structure
2. Conduit which has less than $2^{1/2}$ inches inside diameter

Note c: Seismic restraints are not required for any one of the following conditions for other pipe systems

1. Piping suspended by individual hangars 12 inches or less in length from the top of the pipe to the supporting structure
2. Piping in boiler and mechanical rroms which has less than 1¼ inches inside diameter.
3. Piping in other areas which has less than 2½ inches inside diameter.

Note d: Seismic restraints are not required for any one of the following conditions for HVAC ducts:

1. Ducts suspended by individual hangars 12 inches or less in length from the top of the duct to the supporting structure
2. Ducts which have a cross-sectional area less than 6 square feet.

Note e: Pendulum lighting fixtures sahll be designed based on a component seismic coefficient *(C_C)* of 1.5. The vertical supportshall be designed with a factor of safety of 4.0

Table 1612.7.4(2)
ATTACHMENT AMPLIFICATION

FACTOR (a_c)

Component mounting system	Attachment amplification factor (a_a)
Fixed of direct connection	1.0
Resilient-mounting system	
Seismic-activated restraining device	1.0
Elastic restraining device where:	
$\frac{T_c}{T} < 0.6$ or $\frac{T_c}{T} > 1.4^a$	1.0
$\frac{T_c}{T}$? 0.6 or $\frac{T_c}{T}$? 1.4^a	2.0

Note a: T is the fundemental period of the building, in seconds, determined by 780 CMR 1612.5.1.2 or 780 CMR 1612.6.4. T_c is the fundemental period, in seconds, of the component and its attachement determined by 780 CMR 1612.7.4.1

K = Slope of the load vs deflection curve (Ib./in.) at the point of loading.

Alternatively, the fundamental period of the component *(T_C)*, in seconds, shall be determined by experimental test data or by a properly substantiated analysis.

1612.7.4.2 Component attachment: Systems, components and the means of their attachment shall be designed to accommodate relative seismic displacements between points of support. Displacements at points of support shall be determined in accordance with 780 CMR 1612.5.5 or 1612.6.8. Relative lateral displacements at points of support shall be determined considering the difference in elevation between the supports and considering full out-of-phase displacements across portions of the building that are capable of moving in a differential manner such as at seismic and expansion joints. Anchor bolts shall be designed for combined shear and tension. Restraining devices shall be provided to limit the horizontal and vertical motions, to prevent component resonance and to prevent overturning.

1612.7.4.1 Component period: The fundamental period of the component and its attachments (T_c), in seconds, shall be determined by the following formula:

$$T_c = 0.32\sqrt{\frac{W_c}{K}}$$

where:

W_c = Weight of the component (Ibs.).

For stable resilient-mounting attachments:

K = Spring stiffness constant (Ib./in.).

For other resilient-mounting attachments:

1612.7.5 Elevator design requirements: The design and construction of elevators and elevator components in buildings assigned to Seismic Performance Category D or E, in accordance with 780 CMR 1612.2, shall comply with the requirements in Appendix F of ASME A17.1 listed in ***Appendix A***.

780 CMR 1613.0 CONCENTRATED LOADS

1613.1 General: Floors and roofs of buildings in the locations specified in Table 1613.1 shall be designed to support the uniformly distributed *live loads* prescribed in 780 CMR 1606.0 or the minimum concentrated *loads* in pounds prescribed in Table 1613.1, whichever produces the greater stresses. If the anticipated actual *loads* are higher, the actual *loads* shall be utilized. Unless otherwise specified, the indicated concentration shall be assumed to occupy an area of 2½ square feet and shall be so located as to produce the maximum stress conditions in the structural members.

Table 1613.1
MINIMUM CONCENTRATED LOADS

Location	Load (pounds)[a]
Elevator machine room grating (on area of 4 square inches)	300

Finish light plate floor construction (on area of 4 square inches)	200
Garages	See 780 CMR 1613.2
Greenhouse roof bars, purlins and rafters	100
Hospitals and ward rooms	1,000
Libraries	1,000
Manufacturing and storage buildings	2,000
Mechanical equipment	See 780 CMR 1613.3
Mercantile areas	2,000
Office	2,000
Schools	1,000
Scuttles, skylight ribs and accessible ceiling ribs and hangers (over an area of one suare inch)	200
Sidewalks or vehicular driveways subject to trucking	8,000
Stair treads (over area of 4 square inches at center of tread)	300

Note a: 1 pound = 4.448 N; 1 square inch=645.16 mm^2

1613.2 Garages: Minimum concentrated *loads* for garages or portions of buildings occupied for parking motor vehicles shall be:

1. For passenger cars accommodating not more than nine passengers, 2,000 pounds (8896 N) acting on an area of 20 square inches (12900 mm^2);
2. Mechanical parking structures without slab, passenger cars only, 1500 pounds (6672 N) per wheel; and
3. For trucks or buses, on slabs, applicable wheel loads and tire contact areas specified in AASHTO Standard Specification for Highway Bridges with interim revisions to 1995 (see ***Appendix A***).

1613.3 Mechanical Equipment: The actual concentrated *loads* of the machinery, shall be used for buildings containing mechanical material handling equipment, machines or other heavy apparatus.

780 CMR 1614.0 IMPACT LOADS

1614.1 General: The *live loads* specified in 780 CMR 1606.0 shall be assumed to include adequate allowance for ordinary impact conditions. Provisions shall be made in the structural design for special occupancies and *loads* which involve vibration and impact forces. Where dynamic effects such as resonance and fatigue are likely to be important as a result of cyclical loading, a dynamic analysis shall be carried out.

1614.2 Elevators: Structural supports for elevators, dumbwaiters, escalators and moving walks shall be designed for the *loads* and within the limits of the deflection specified in the Massachusetts State Department of Public Safety, Board Elevator Regulations (524 CMR 1.0 through 34.0), listed in ***Appendix A***. (In accordance with the Regulations, all suspended elevator *loads* shall be increased 100% for impact.

1614.3 Machinery: For the purposes of design, the weight of machinery and moving *loads* shall be increased as follows to allow for impact:

Elevator machinery 100%
Light machinery, shaft- or motor-driven...... 20%
Reciprocating machinery or power-driven units 50%

These percentages shall be increased where so specified by the manufacturer.

1614.4 Hangers for floors and stairs: *Live loads* on hangers supporting floors or stairs shall be multiplied by an impact factor of 1.33.

780 CMR 1615.0 SPECIAL LOADS

1615.1 General: Provisions shall be made for all special *loads* herein prescribed and all other special *loads* to which the building or structure is subjected.

1615.2 Hydrostatic uplift: All foundation slabs and other footings subjected to water pressure shall be designed to resist an uplift equal to the full hydrostatic pressure. All foundation slabs, footings and walls of buildings located in flood-hazard zones (A Zones) and high-hazard zones (V Zones) shall be designed to resist uplift and lateral *loads* associated with hydrostatic pressure resulting from flooding to the base flood elevation. Counteracting weight shall be reduced to 0.85 times the actual weight.

1615.3 Hydrodynamic loads: For buildings located in flood-hazard zones (A Zones) or high-hazard zones (V Zones), all structural components located below the base flood elevation shall be designed to resist hydrodynamic forces resulting from velocity waters during flooding to the base flood elevation.

1615.4 Partitions and Interior Finish: Partitions, their components and other interior finish shall have adequate strength to resist a horizontal load of not less than 5 psf.

1615.5 Guardrails and handrails: All required guardrails and handrails shall be designed and constructed to the structural loading conditions set forth in Table 1615.5. without exceeding the allowable design working stresses of the materials, anchorage and connecting devices utilized. The allowable working stresses shall be as defined by the appropriate design standard. Each load shall be applied so as to produce the maximum stress in each of the respective components.

Each load shall be applied in the direction indicated in the table. The concentrated load and uniformly distributed *loads* need not be applied simultaneously. The *loads* applied to in-fill areas need not be applied simultaneously with the *loads* applied on the top railing.

TABLE 1615.5
LOADS ON GUARDRAILS AND HANDRAILS

Type of Occupancy	Location of Load	Type of load	Direction of Load	Magnitude of Load
All	Handrails	Concentrated	Any	200 lb.
All, except dwelling units in Use Groups R-2 and R-3	Handrails	Uniformly distributed	Any	50 lb/ft.
All, except as noted otherwise	Guardrails, top railing members	Concentrated	Any	200 lb.
All, except dwelling units in Use Groups R-2 and R-3 and as noted otherwise	Guardrails, top railing members	Uniformly distributed	Vertical simultaneously with horizontal	100 lb/ft 50 lb/ft.
All	Guardrails, in-fill areas	Concentrated	Any	200 lb. applied over 1 sf. area
Grandstands, stadia, arenas, and similar structures used for public assembly	Guardrails, top railing members	Concentrated	Any	300 lb.
Grandstands, stadia, arenas, and similar structures used for public assembly	Guardrails, top railing members	Uniformly distributed	Any	100 lb/ft

1615.6 Grandstands, stadia and similar structures shall be designed to resist, in combination with design *wind loads*, a horizontal swaying load applied parallel to the row of seats of not less than 24 pounds per lineal foot of seats per row, or in combination with wind, a horizontal swaying load applied transversely of not less than ten pounds per lineal foot of seats per row. Foot boards and seat boards shall be designed for a minimum vertical load of 120 lb. per lineal foot.

1615.7 Horizontal crane loads: A lateral force shall be applied perpendicular (normal) to the span of runway beams and a lateral force shall be applied parallel (longitudinal) to the beam span.

(a) The lateral force acting normal to the runway shall be applied at the top of the rail, and shall be 20% for power-operated crane trolleys, and 10% for hand-operated trolleys, of the sum of the weights of the maximum lifted load and of the crane trolley. This force shall be distributed to tributary supporting structural members based on the relative lateral stiffness of each component structure supporting the rails.

(b) The longitudinal force acting parallel to the runway and applied at the top of the rail shall be 10% of the maximum wheel *loads* of the crane.

(c) Reductions in these *loads* may be permitted if substantiating technical data acceptable to the building official is provided.

(d) These *loads* need not be considered in combination with *wind loads*.

1615.8 Temperature loads: Movements, and forces resulting from restraint of movements, produced by changes in temperature shall be considered in the design of buildings and structures.

780 CMR 1616.0 COMBINATION OF LOADS

1616.1 General: Combinations of structural *loads* shall be considered in accordance with 780 CMR 1616.0. *Live loads* may be reduced as appropriate in accordance with 780 CMR 1616.0. In addition to the load combinations listed, the following shall be considered in design: structural effects of *loads* due to fluids, *loads* due to the weight and lateral pressure of soil and water in soil, rain *loads* including ponding, and effects arising from contraction or expansion resulting from temperature changes, shrinkage, moisture changes, creep in component materials, and movement due to differential settlement.

1616.1.1 Design Methods: As permitted by the structural design standards listed in ***Appendix A***, the structural designer may use either the allowable stress design method (also called working stress design) or the strength design method (also called limit states design, load and resistance factor design, or ultimate strength design). The applicable load combinations given in 780 CMR 1616.1 shall govern over the load combinations given in the design standards in ***Appendix A***.

Exception: Use load combinations from design standards in ***Appendix A*** which do not include wind or seismic *loads*, if those combinations produce a more unfavorable effect in the structure or foundation.

1616.2 Load Combinations Using Allowable Stress Design

1616.2.1 Basic Combinations. All *loads* listed herein shall be considered to act in the following combinations, whichever produces the most unfavorable effect in the building, foundation or structural member being considered. The most unfavorable effect may occur when one or more of the contributing *loads* is not acting.

1. Dead
2. Dead + floor live + roof live (or snow)
3. Dead + floor live + 0.5 roof live (or 0.5 snow) + wind
4. Dead + floor live + roof live (or snow) + 0.5 wind
5. 0.67 Dead - wind
6. 0.67 Dead - 0.8 seismic
7. Dead + 0.9 floor live + 0.6 snow + 0.8 seismic

1616.3 Load Combinations Using Strength Design

1616.3.1 Basic Combinations. All *loads* listed herein shall be considered to act in the following factored load combinations, whichever produces the most unfavorable effect in the building, foundation or structural member being considered. The most unfavorable effect may occur when one or more of the contributing *loads* is not acting.

1. 1.4 Dead
2. 1.3 Dead + 1.6 floor live + 0.5 roof live (or 0.5 snow)
3. 1.3 Dead + 0.5 floor live + 1.6 roof live (or 1.6 snow)
4. 1.3 Dead + 0.5 floor live + 0.5 roof live (or 0.5 snow) + 1.3 wind
5. 1.3 Dead + 1.6 roof live (or 1.6 snow) + 0.8 wind
6. 0.9 Dead - 1.3 wind
7. 1.3 Dead + 1.0 floor live + 0.7 snow + 1.0 seismic
8. (0.90 - 0.5 A_V) Dead - 1.0 seismic

Exception: The load factor on floor *live load* in combinations 3 and 4 shall equal 1.0 for garages, areas occupied as places of public assembly, and all areas where the floor live load is greater than 100 pounds per square foot.

1616.4 Amplification of seismic load effects for special conditions: Seismic load effects shall be amplified by the factor 2R/5, where 2R/5 shall be not less than 1.0, in allowable stress design 780 CMR 1616.2.1, and in strength design 780 CMR 1616.3.1 for the following conditions. Note: In allowable stress design load combinations 6 and 7, the term "0.8 seismic" shall be replaced by "0.8(2R/5) seismic".

1. For computing the design forces in members such as columns, girders or trusses which support discontinuous lateral force-resisting elements when using Load Combination 7 in 780 CMR 1616.2.1 (Allowable Stress Design) or Load Combination 7

in 780 CMR 1616.3.1 (Strength Design). However, the computed forces in such members need not exceed the capacity of other elements of the structure to transfer such forces into these members. The capacity of the other elements to transfer such forces shall not be less than 1.25 times the computed design strengths of the other elements.

2. For computing the design forces in members and connections that do not develop the full strength of the weaker member connected when using Load Combination 6 in 780 CMR 1616.2.1 (Allowable Stress Design) or Load Combination 8 in 780 CMR 1616.3.1 (Strength Design). However, the design forces need not exceed the limit determined by the capacity of the foundation to resist overturning uplift.

1616.5 Counteracting Load: Where the effects of design *loads* counteract one another in a structural member or joint, the design shall account for and shall ensure adequate safety for possible stress reversals.

1616.6 Stress Increases: All allowable stresses and soil load-bearing values specified in 780 CMR for allowable stress design are permitted to be increased one-third where *wind load* or seismic load combinations are utilized.

1616.7 Crane hook *loads* are not required to be combined with the roof *live load*, nor with seismic load, nor with more than 0.75 of the snow load or one-half of the *wind load*

780 CMR 1617.0 EXISTING BUILDINGS

1617.1 General: The repair, reconstruction, alteration, addition to or change in use or occupancy of existing buildings shall comply with 780 CMR 34.

1617.2 Posted live load: When floor *live loads* required by the Code have been increased from those heretofore approved for a building or structure in a particular use group and there is no change to a new use requiring greater floor *loads* than those currently required for the original use group, the floors so affected may be posted for the originally approved *live loads*, provided the building is structurally safe in all its parts, is adequate for its existing use, and the public safety is not endangered thereby.

NON-TEXT PAGE